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# Japan Report

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MARITIME OBSERVATION SATELLITE PROPOSAL

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21 March 1983

## JAPAN REPORT

No. 168

### MARITIME OBSERVATION SATELLITE PROPOSAL

Tokyo NEC MOS-1 in Japanese Oct 79 pp 2-27

[Text] This booklet contains the outline of a proposal by Nippon Electric Company [NEC] on the Maritime Observation Satellite No 1 (MOS-1), which was planned by the National Space Development Agency.

The main features of our proposal are listed below.

- We have adopted the bias momentum method, which is based on our past achievement, is reliable, and works very well.
- We propose module construction, which is expandable for future work and easy to integrate.
- Our development work will be based on independent, domestic technology that has grown from local fabrication of many satellites.

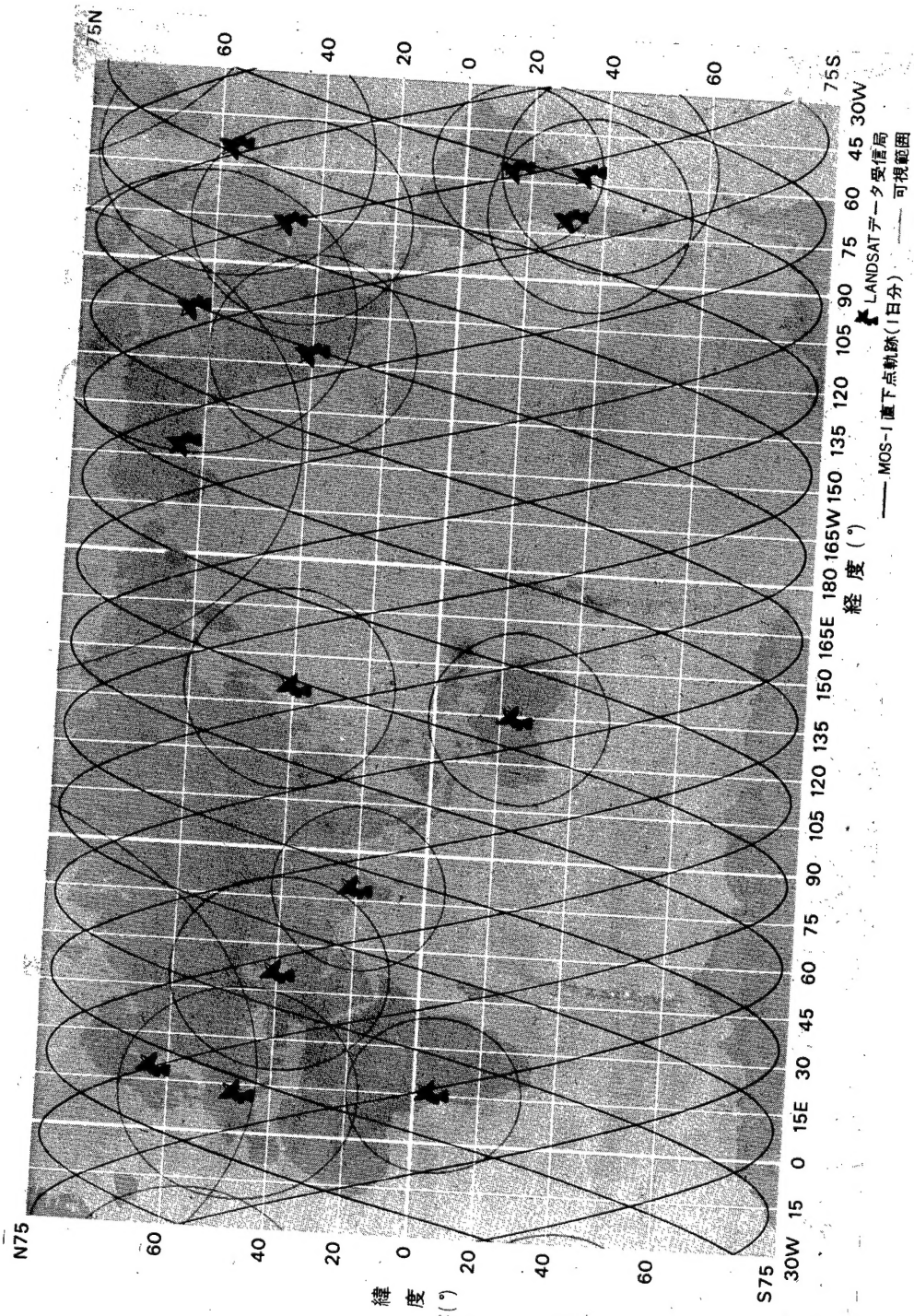
MOS-1 will be the first Japanese satellite for observation of the earth. It will serve as a part of the development of the earth observation system, which will contribute to the effective use of our resources and the preservation of our environment. In order to observe maritime phenomena and to establish technology that is common to earth observation satellites, MOS-1 is intended to fulfill the following missions:

- To observe the chromaticity and temperatures of ocean surfaces by a radiometer for visible and near infrared radiation (MESSR), a radiometer for visible and thermal infrared radiation (VTIR), and a microwave radiometer (MSR).
- To learn operating techniques for solar synchronous satellites.
- To learn operating techniques for earth observation satellites.
- To carry out basic experiments in position determination by using a data collection system.
- To establish technology for domestic production of three-axes satellites.

Based on our achievements and experience as the integrator of many domestically produced satellites, NEC has been accumulating technology for three-axes satellites from our own research and development. We have also been developing the MESSR, which is an instrument for the major mission of MOS-1. The development of MOS-1 will be based on these achievements and it will follow the basic policies listed below:

- To utilize locally developed technology based on our achievements and experience as the integrator of more than 10 domestically produced satellites.
- To provide flexible on-board equipment to carry out the satellite's mission, and to assure expanded applications for future satellites.
- To obtain technical support from foreign partners in order to assure the completion of the mission and to minimize risks in development.

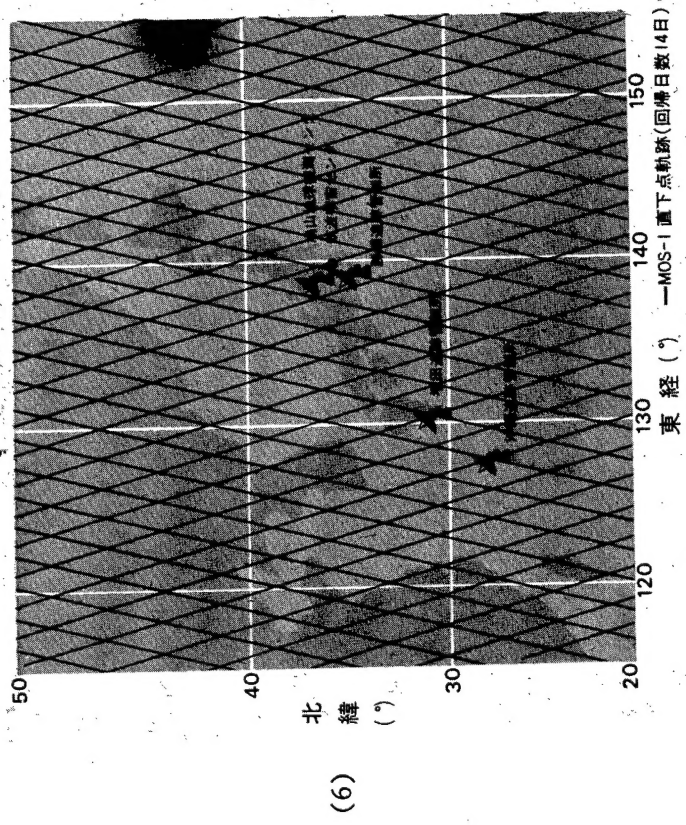
| Contents  | [Original page number] |
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| Mission.....                                    | 5                      |
| Satellite configuration and major data.....     | 6                      |
| Attitude orbit control system.....              | 10                     |
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| Equipment for carrying out the mission.....     | 22                     |
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(1)

(4)  
(5)

(2) (3)



The MOS-1 comprehensive system consists of the MOS-1 satellite, which circles on a quasi-recurring, solar synchronous orbit at an altitude of 913 km, data receiving stations that receive and utilize observation data, and tracking and control stations that launch, track, and control the satellite. The data transmitted from MOS-1 can be received not only by Japan but also by foreign data receiving stations.

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- (13)

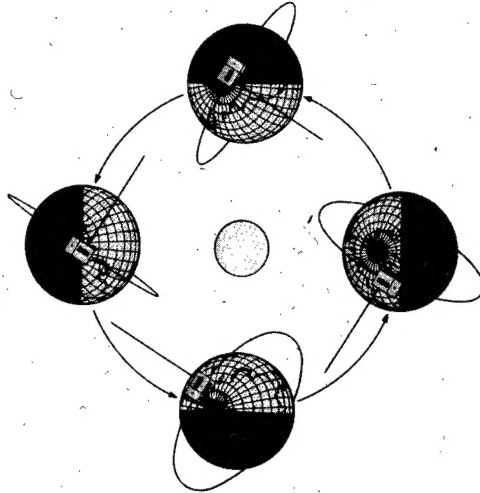
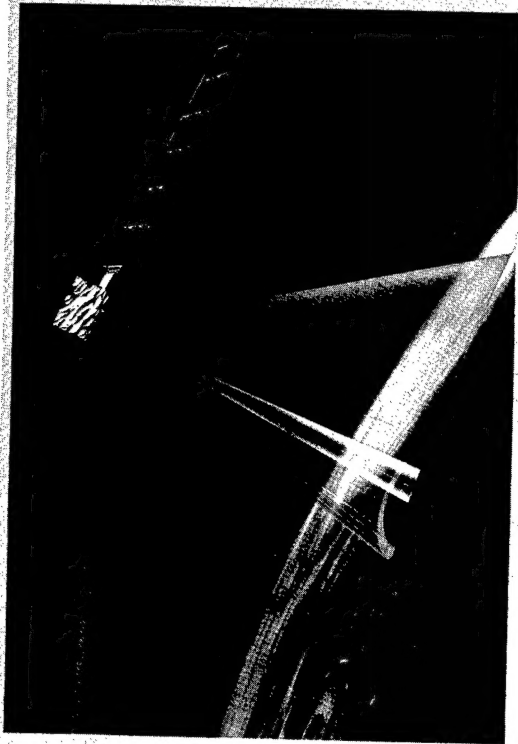
(7) (8)

|      |   |
|------|---|
| Key: |   |
| (1)  | Latitude  |
| (2)  | Longitude   |
| (3)  | Terrestrial projection of MOS-1 orbit (one day)             |
| (4)  | Landsat data receiving stations                             |
| (5)  | Visible range   |
| (6)  | Northern latitude   |
| (7)  | Eastern longitude   |
| (8)  | Terrestrial projection of MOS-1 orbit recurs every 14 days) |
| (9)  | Hatoyama earth observation center                           |
| (10) | Tsukuba earth observation center                            |
| (11) | Katsuura tracking control center                            |
| (12) | Masuda " "  |
| (13) | Okinawa " "   |

## Satellite Mission

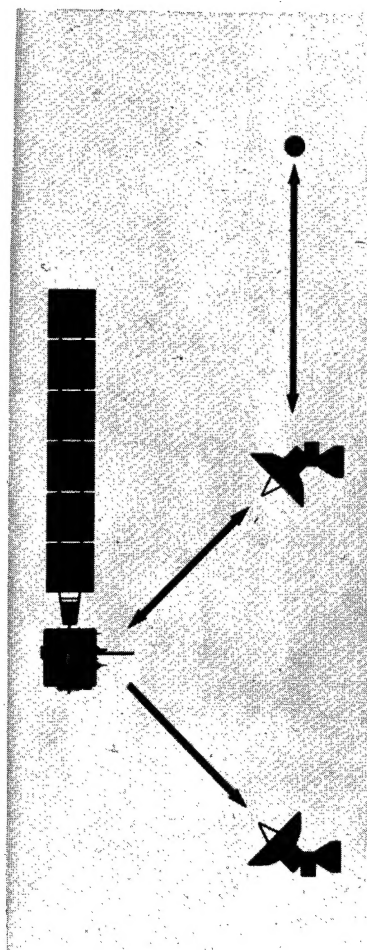
- Oceanic observation by equipment → on board.
- The data observed by MESSR and VTIR are sent to the ground by an 8.4 GHz transmitter. The instruments will be used mainly to observe pollution of the ocean surface, ocean color, sea ice, plant distribution, temperature distribution in the ocean surface, and the distribution of cloud and water vapor.
- The data observed by MSR will be transmitted by USB and telemetry data. The data will be used to observe the distribution of water vapor in the atmosphere and sea and drifting ice.

- To learn how to operate a solar → synchronous satellite.  
The satellite's attitude is arrested immediately after it is separated from its launcher by checking the initial conditions of the satellite. These controls and commands to extend the solar cell paddle will be handled by the Tsukuba Space Center through down range stations in South America. The maintenance of the solar synchronous orbit (the calculation of errors in orbit and attitude and their correction operations) and the operation of the satellite (surveillance of satellite conditions and control manipulations) will also be carried out by the Tsukuba Space Center through tracking and control stations in Okinawa, Katsuura and Masuda.



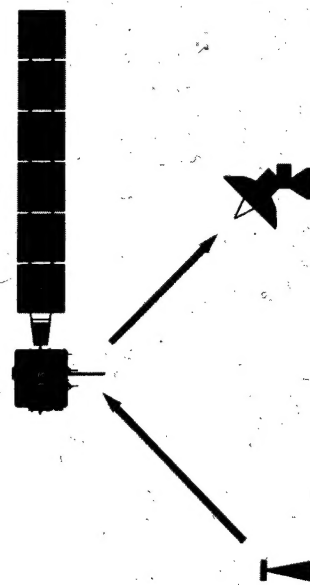
- To learn how to operate an earth observation satellite. →

The observation data will be received mainly by the Earth Observation Center and some overseas data receiving stations. The Earth Observation Center will operate the instruments on board by exchanging information with the Tsukuba Space Center.



- To carry out basic experiments, such as position determination, using DCS. →

By using relays for the data collection system (DCS), basic experiments in position determination for research and rescue operations will be carried out.



## Satellite Configuration and Major Data

To carry out maritime observation, MOS-1 will be launched in the winter of 1984 from the Tanegashima Space Center by an N-II rocket launcher. The satellite will be put into a solar synchronous orbit of altitude 913 km and inclination 99.1°. The weight of the satellite when it is launched will be about 730 kg.

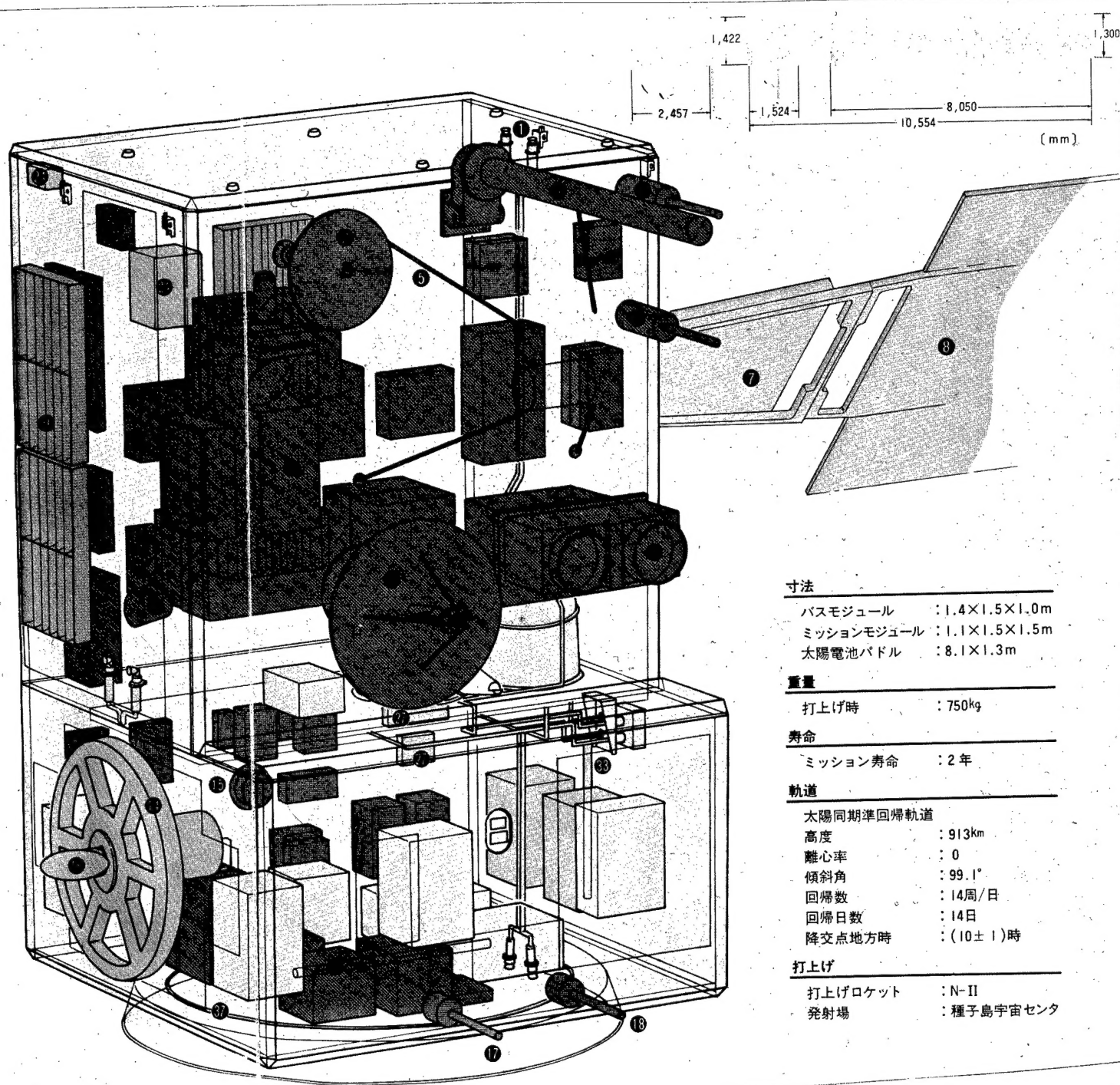
In this satellite, we have adopted a module construction that has high integration efficiency and can be easily expanded to other tasks. The satellite consists of two rectangular parallelepiped modules, i.e., a bus module and a mission module. Observational instruments and communication antennae are located on the side with the largest area with sufficient fields of vision.

The interface adaptor of the rocket is located at the bottom of the bus module, and the scan wheel assembly is attached on one side. Important instruments such as the attitude orbit control system, the gas jet system, the power supply system, and the telemetry/command system are mounted inside this module.

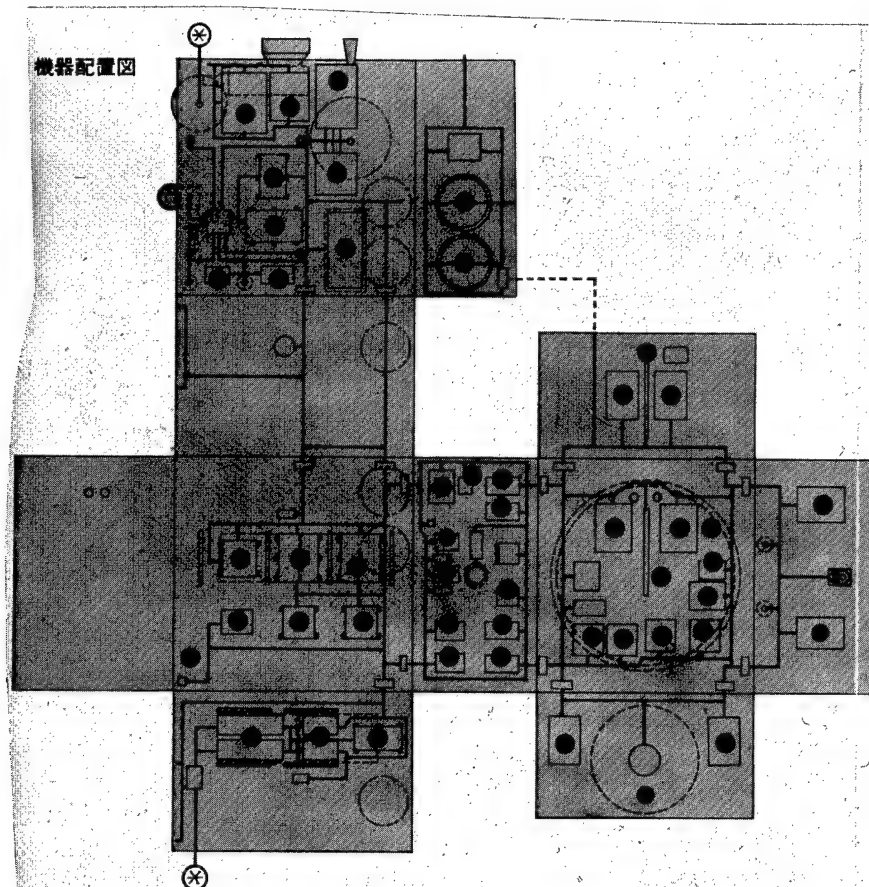
MESSR, the high speed data transmission section, VTIR, MSR, and the antenna system are mounted on the mission module. The solar cell paddle is also mounted on this module, and it is arranged to optimize the generated power according to the tasks to be performed. The generating capacity of MOS-1 toward the end of its useful life will be 590 watts.

### Special features

- The solar cell paddle is built to form one sheet in order to secure the greatest field of vision for the instruments on board.
- By using the module construction, integration has been made easy and instruments can be expanded for other tasks.
- The bias momentum method has been adopted to improve its reliability and usefulness.
- Thermal control has been made safe by using both passive and active thermal control methods.
- The existing facilities are used effectively by using the same telemetry/command method as the one that is used for ETS-III [satellite]. Stored command and stored data methods are also used, and the satellite can be operated from Japan alone.
- The adopted configuration has sufficient spare electric power, and observed data can be sent to foreign data receiving stations.



# Arrangement of Equipment



## Key:

- |   |   |
|---|---|
| 1. Thrusters                                    | 24. Terrestrial magnetism sensor and electronic equipment to process the data |
| 2. X-band antenna                               | 25. MESSR signal processing section   |
| 3. DCS/SAR up-link antenna                      | 26. High speed data transmission section                                      |
| 4. USB antenna                                  | 27. Sun sensors and electronic equipment to process the data                  |
| 5. VHF antenna                                  | 28. VHF receivers   |
| 6. DCS/SAR down-link antenna                    | 29. VHF transmitters  |
| 7. Shunt dissipater                             | 30. S-band receivers  |
| 8. Solar cell panel                             | 31. Signal synthesizing circuit   |
| 9. Thermal louver                               | 32. S-band transmitters   |
| 10. Visible, thermal infrared radiometer (VTIR) | 33. Magnetic momentum control coil  |
| 11. Sky horn                                    | 34. Electronic equipment for attitude orbit control                           |
| 12. Microwave radiometer (MSR)                  | 35. Magnetic attitude control coil  |
| 13. Visible, near infrared radiometer (MESSR)   | 36. Boost converters  |
| 14. Momentum wheel                              | 37. Nutation damper   |
| 15. S-band transition antenna                   | 38. Data recorders  |
| 16. Earth sensor                                | 39. Telemetry encoders  |
| 17. S-band up-link antenna                      | 40. Command decoders  |
| 18. S-band down-link antenna                    | 41. Power supply control unit   |
| 19. MSR signal processing and driving sections  | 42. Batteries   |
| 20. MESSR and its controllers                   |   |
| 21. Propellant tanks                            |   |
| 22. DCS/SAR relays                              |   |
| 23. VTIR signal processing section              |   |

Size

|                   |                   |
|-------------------|-------------------|
| Bus module        | 1.4 x 1.5 x 1.0 m |
| Mission module    | 1.1 x 1.5 x 1.5 m |
| Solar cell paddle | 8.1 x 1.3 m       |

Weight

|               |        |
|---------------|--------|
| Launch weight | 750 kg |
|---------------|--------|

Lifetime

|                  |         |
|------------------|---------|
| Mission lifetime | 2 years |
|------------------|---------|

Orbit

Solar synchronous, quasirecurring orbit

|                                   |                    |
|-----------------------------------|--------------------|
| Altitude                          | 913 km             |
| Eccentricity                      | 0                  |
| Inclination                       | 99.1°              |
| Number of revolutions             | 14 revolutions/day |
| Recurrency period                 | 14 days            |
| Local time at the descending node | 10±1 o'clock       |

Launching

|             |                          |
|-------------|--------------------------|
| Launcher    | N-II                     |
| Launch site | Tanegashima Space Center |

Attitude orbit control system

|                                |   |
|--------------------------------|---|
| Three-axes control method      | Bias momentum   |
| Attitude control precision     | Pitch/roll ±0.2°<br>Yaw ±0.7°   |
| Drift rate                     | Pitch/roll ±0.01°/second<br>Yaw ±0.02°/second                               |
| Momentum wheel                 | 100 Nms   |
| Magnetic attitude control coil | 50 ATm <sup>2</sup>   |
| Magnetic momentum control coil | 20 ATm <sup>2</sup>   |
| Passive nutation damper        |   |
| Sensors                        | Conical scanning earth sensor<br>Sun sensor<br>Terrestrial magnetism sensor |

### Gas jet system

|                       |                   |
|-----------------------|-------------------|
| Orbit control thrusts | 1 newton x 6      |
| Propellant            | Hydrazine 19.6 kg |
| Number of tanks       | 2                 |

### Power supply system/solar cell paddle system

#### Solar cell paddle

|                      |                               |
|----------------------|-------------------------------|
| Panel driving method | One-axis clock control method |
| Panel area           | 10 m <sup>2</sup>             |
| Solar cells          | (2 cm x 2 cm) 21,996 cells    |
| Glass cover          | 0.3 mm thick                  |
| Power generation     | BOL 670 W; EOL 590 W          |

#### Charge regulator type power supply

|             |                |
|-------------|----------------|
| Bus voltage | 29V            |
| Batteries   | NiCd 15 AH x 3 |

|                             |   |
|-----------------------------|---|
| Satellite power consumption | 519 W (148 W for bus equipment,<br>371 W for mission equipment) |
|-----------------------------|---|

### Airframe System

#### Modular bus mission equipment

Single sheet panel (folded six times)

#### Size

|                   |                   |
|-------------------|-------------------|
| Bus module        | 1.4 x 1.5 x 1.0 m |
| Mission module    | 1.1 x 1.5 x 1.5 m |
| Solar cell panels | 8.1 x 1.3 m       |

#### Weight

|                   |              |
|-------------------|--------------|
| Total             | About 750 kg |
| Bus equipment     | 470 kg       |
| Mission equipment | 212 kg       |
| Propellant        | 20 kg        |
| Margin            | 49 kg        |

### Thermal control system

|                         |   |
|-------------------------|---|
| Active thermal control  | Thermal louvers, heaters, bimetals      |
| Passive thermal control | Radiators, thermal blankets, condensers |

Communication system/antenna system

|        |              |          |  |  |
|--------|--------------|----------|--|--|
| VHF    | Telemetry    | 136 MHz  | } Monopole antenna x 4   |  |
|        | Command      | 148 MHz  |  |  |
| UHF    | DCS/SAR up   | 406 MHz  | Quadrifilar helical antenna x 1  |  |
| L-band | DCS/SAR down | 1543 MHz | Quadrifilar helical antenna x 1  |  |
| S-band | Telemetry    | 1.7 GHz  | { Quadrifilar helical antenna x 2<br>Spiral antenna (for transition)x1 |  |
|        | R & RR       |          |  |  |
|        | Command      | 2.1 GHz  |  |  |
|        | R & RR       |          |  |  |
|        | R & RR       | 2.1 GHz  |  |  |
| USB    | Telemetry    | 2.2 GHz  | Quadrifilar helical antenna x 1  |  |
|        | MSR          |          |  |  |
| X-band | MESSR, VTIR  | 8.4 GHz  | Turnstyle antenna x 1  |  |

Telemetry/command system

Data stored during the invisible period and high speed playback during the visible period

Stored commands

Telemetry encoder

|                 |           |
|-----------------|-----------|
| Bit rate        | 1,024 bps |
| Number of entry | About 480 |

Command decoder

|                 |                         |
|-----------------|-------------------------|
| Bit rate        | 128 bps                 |
| Number of entry | Maximum 252 (real time) |
|                 | Maximum 16 (stored)     |

Data recorder

|                       |                       |
|-----------------------|-----------------------|
| Input channel         | 1 channel (2 tracks)  |
| Bit rate              | 1,024 bps (recording) |
|                       | 26,624 (playback)     |
| Playback/record ratio | 26/1                  |
| Recording time        | Minimum 105 minutes   |
| Playback time         | Minimum 4 minutes     |

Mission equipment

MESSR

Band 1 0.5 - 0.6  $\mu\text{m}$   
2 0.6 - 0.7  $\mu\text{m}$   
3 0.7 - 0.8  $\mu\text{m}$   
4 0.8 - 1.1  $\mu\text{m}$

VTIR

Band 1 0.5 - 0.7  $\mu\text{m}$   
2 6.0 - 7.0  $\mu\text{m}$   
3 10.5 - 11.5  $\mu\text{m}$   
4 11.5 - 12.5  $\mu\text{m}$

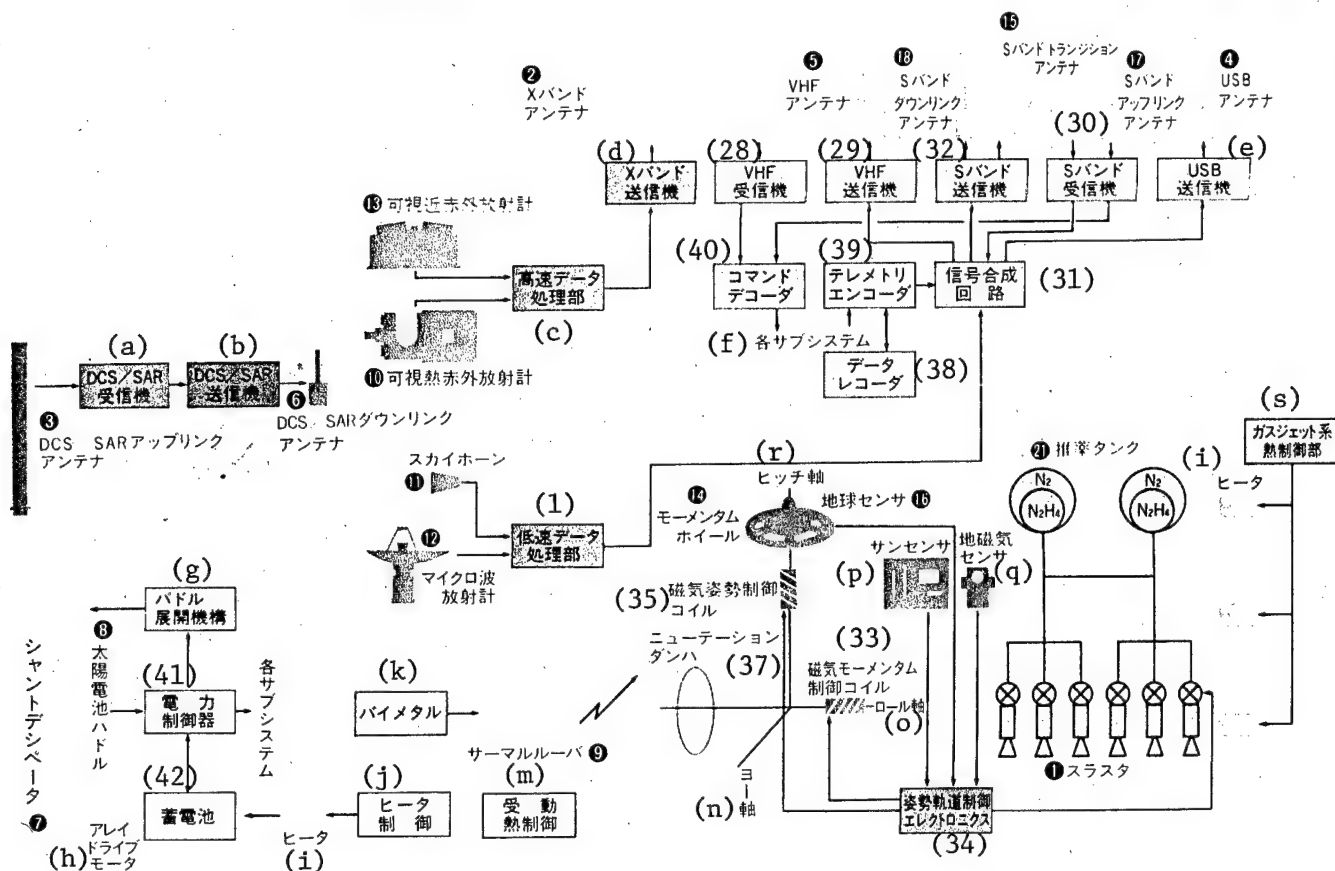
MSR

Band 1 23 GHz  
2 31 GHz

DCS/SAR relay (DCS/SAR)

Up 406 MHz  
Down 1,543 MHz

# System functions



## Key:

- (a) DCS/SAR receiver
- (b) DCS/SAR transmitter
- (c) High speed data processing section
- (d) X-band transmitter
- (e) USB transmitter
- (f) Each subsystem
- (g) Paddle extension mechanism
- (h) Array drive motor
- (i) Heater
- (j) Heater control
- (k) Bimetal
- (l) Low speed data processing section
- (m) Passive thermal control
- (n) Yaw axis
- (o) Roll axis
- (p) Sun sensor
- (q) Terrestrial magnetism sensor
- (r) Pitch axis
- (s) Gas jet system, thermal control section

[key continued]

[continuation of key]

1. Thrusters
2. X-band antenna
3. DCS/SAR up-link antenna
4. USB antenna
5. VHF antenna
6. DCS/SAR down-link antenna
7. Shunt dissipater
8. Solar cell panel
9. Thermal louver
10. Visible, thermal infrared radiometer (VTIR)
11. Sky horn
12. Microwave radiometer (MSR)
13. Visible, near infrared radiometer (MESSR)
14. Momentum wheel
15. S-band transition antenna
16. Earth sensor
17. S-band up-link antenna
18. S-band down-link antenna
19. MSR signal processing and driving sections
20. MESSR and its controllers
21. Propellant tanks
22. DCS/SAR relays
23. VTIR signal processing section
24. Terrestrial magnetism sensor and electronic equipment to process the data
25. MESSR signal processing section
26. High speed data transmission section
27. Sun sensors and electronic equipment to process the data
28. VHF receivers
29. VHF transmitters
30. S-band receivers
31. Signal synthesizing circuit
32. S-band transmitters
33. Magnetic momentum control coil
34. Electronic equipment for attitude orbit control
35. Magnetic attitude control coil
36. Boost converters
37. Nutation damper
38. Data recorders
39. Telemetry encoders
40. Command decoders
41. Power supply control unit
42. Batteries

Table. Allocation of Weight, Electric Power and Reliability

|   | Weight<br>allocation<br>(kg) | Electric<br>power<br>allocation<br>(watt) | Reliability<br>allocation  |
|---|------------------------------|---|----------------------------|
| Attitude orbit control system             | 50.7                         | 14.3* <sup>1</sup>                        | 0.8971                     |
| Telemetry/command system                  | 32.0                         | 32.1                                      | 0.9725* <sup>8</sup>       |
| Communication system                      | 20.1                         | 30.6* <sup>2</sup>                        | 0.9725                     |
| Antenna system                            | 10.7                         | --  | 0.9938                     |
| Power supply system                       | 94.8* <sup>3</sup>           | 20.0* <sup>4</sup>                        | 0.9545                     |
| Solar cell paddle system                  | 57.4* <sup>5</sup>           | 13.0                                      | 0.9399                     |
| Gas jet system                            | 18.9                         | 16.0* <sup>6</sup>                        | 0.9516                     |
| Airframe system                           | 120.0                        | --  | 0.9877                     |
| Thermal control system                    | 20.0                         | 22.0* <sup>7</sup>                        | 0.9846                     |
| Mechanical and electrical instrumentation | 45.0                         | --  | (Included in<br>the frame) |
| Bus instruments                           | 469.6                        | 148.0                                     | 0.700* <sup>8</sup>        |
| MESSR                                     | 134.6                        | 200.2                                     |                            |
| VTIR                                      | 20.0                         | 35.0                                      |                            |
| MSR                                       | 54.0                         | 120.0                                     |                            |
| DCS/SAR relay                             | 3.3                          | 16.0                                      |                            |
| Mission instruments                       | 211.9                        | 371.2                                     | 0.794                      |
| Satellite dry weight                      | 681.5                        | 371.2                                     |                            |
| Propellant                                | 19.6                         | --  |                            |
| Margin                                    | 48.9                         | --  |                            |
| Satellite total                           | 750.0                        | 519.2                                     | 0.5* <sup>8</sup>          |

\*1: Increases by 1.0 watt during roll/yaw control, and by 1.3 watts during unloading.

\*2: Increases by 6 watts when VHF TX is turned on.

\*3: Includes the weight of solar cells.

\*4: Increases by a maximum of 83.8 watts when the boost converter is used.

\*5: Does not include the weight of solar cells.

\*6: Increases by 6 watts when a heater is used, and by 9.8 watts when a thruster is blasting.

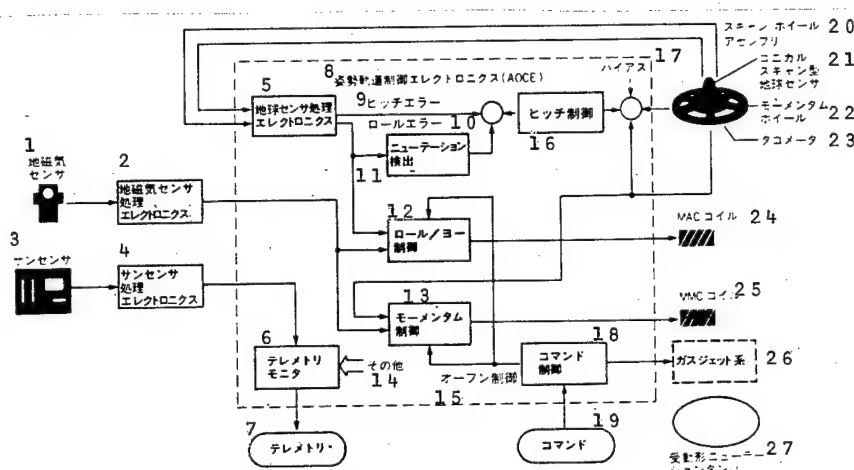
\*7: When a heater is on for orbit [control] only, while mission instruments are turned off.

\*8: Excludes the data recorder (allocation 0.9).

## Attitude Orbit Control System

The bias momentum method is used for the attitude orbit control system. The roll/yaw attitude and pitch control are maintained by a momentum wheel. The unloading and the roll/yaw control of the momentum wheel are controlled by a magnetic control method. Nutation of the satellite after its separation [from the launcher] is removed by a passive nutation damper, and nutation during the orbital operation is removed by an active nutation control. All attitude controls are carried out on board [i.e., not by command from the ground].

- Notable design characteristics
- Reliability and operability are secured by using the bias momentum method.
- Reliability and durability are secured by using a magnetic torquer.
- Long frequency nutation is removed by an active nutation damper.
- Operations are simplified through on-board processing.



### Key:

- |   |   |
|---|---|
| 1. Terrestrial magnetism sensor   | 13. Momentum control                          |
| 2. Electronic equipment for processing the terrestrial magnetism sensor | 14. Others                                    |
| 3. Sun sensors  | 15. Often [transliteration uncertain] control |
| 4. Electronic equipment for processing sun sensors                      | 16. Pitch control                             |
| 5. Electronic equipment for processing the earth sensor                 | 17. Bias                                      |
| 6. Telemetry monitor  | 18. Command control                           |
| 7. Telemetry  | 19. Command                                   |
| 8. Attitude orbit control electronic equipment (AOCE)                   | 20. Scan wheel assembly                       |
| 9. Pitch error  | 21. Conical scan type earth sensor            |
| 10. Roll error  | 22. Momentum wheel                            |
| 11. Detection of nutation   | 23. Tachometer                                |
| 12. Roll/yaw control  | 24. MAC coil                                  |
|   | 25. MMC coil                                  |
|   | 26. Gas jet system                            |
|   | 27. Passive nutation damper                   |

# Major Performance Data for the Attitude Orbit Control System

|  |  |
|--|--|
| Attitude control precision                         | Pitch/roll $\pm 0.2^\circ$ , yaw $\pm 0.7^\circ$                         |
| Attitude drift rate                                | Pitch/roll $\pm 0.01^\circ/\text{sec}$ , yaw $\pm 0.02^\circ/\text{sec}$ |
| Orbit maintenance precision                        | Altitude $913 \text{ km} \pm 390 \text{ m}$                              |
| Orbit control capability                           | Velocity correction to correct [orbit]                                   |
| Insertion errors:                                  |  |
| In-plane control                                   | 14.2 m/sec   |
| Out-of-plane control                               | 12.9 m/sec   |
| Velocity correction to maintain fundamental orbit: |  |
| In-plane control                                   | 10.2 m/sec   |

## Sun sensors

|                 |                              |
|-----------------|------------------------------|
| Type            | : Digital                    |
| Resolution      | : $1/256^\circ$              |
| Precision       | : $1'$                       |
| Field of vision | : $64^\circ \times 64^\circ$ |

## Terrestrial magnetism sensor

|                   |  |
|-------------------|--|
| Type              | : Flux gate                            |
| Measurement range | : $\pm 50,000\gamma$ (all three gates) |
| Precision         | : Less than $\pm 500\gamma$            |

## Momentum wheel

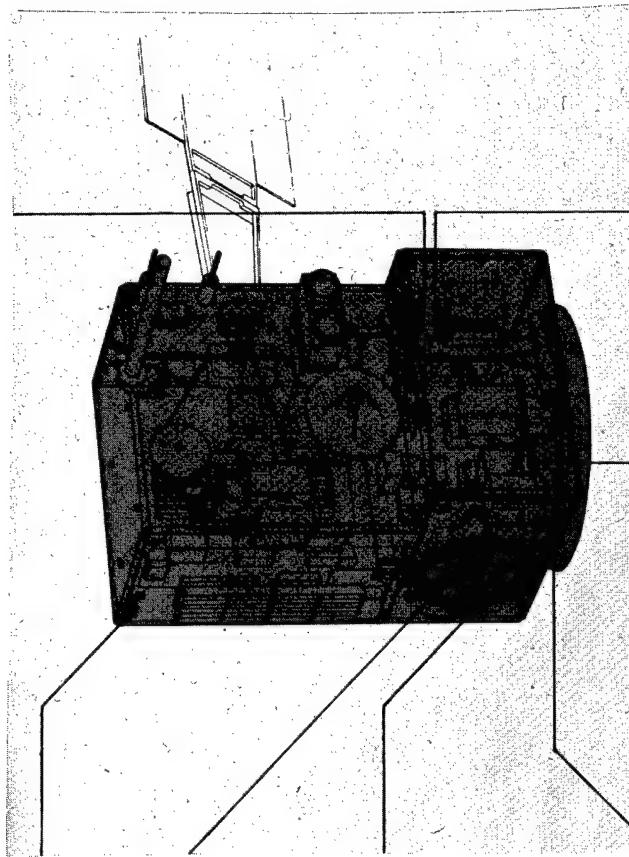
|                 |                            |
|-----------------|----------------------------|
| Moment          | : 100 Nms                  |
| Control torque  | : 0.66 Nms                 |
| Rotation rate   | : 750 rpm $\pm 10$ percent |
| Friction torque | : 0.06 Nm                  |

## Earth sensor

|                        |  |
|------------------------|--|
| Type                   | : Conical scan (mounted on the momentum wheel)   |
| Revolution rate        | : 750 rpm $\pm 10$ percent                       |
| Precision              | : Pitch $\pm 0.14^\circ$ , roll $\pm 0.09^\circ$ |
| Measurement wavelength | : $14 - 16 \mu\text{m}$                          |

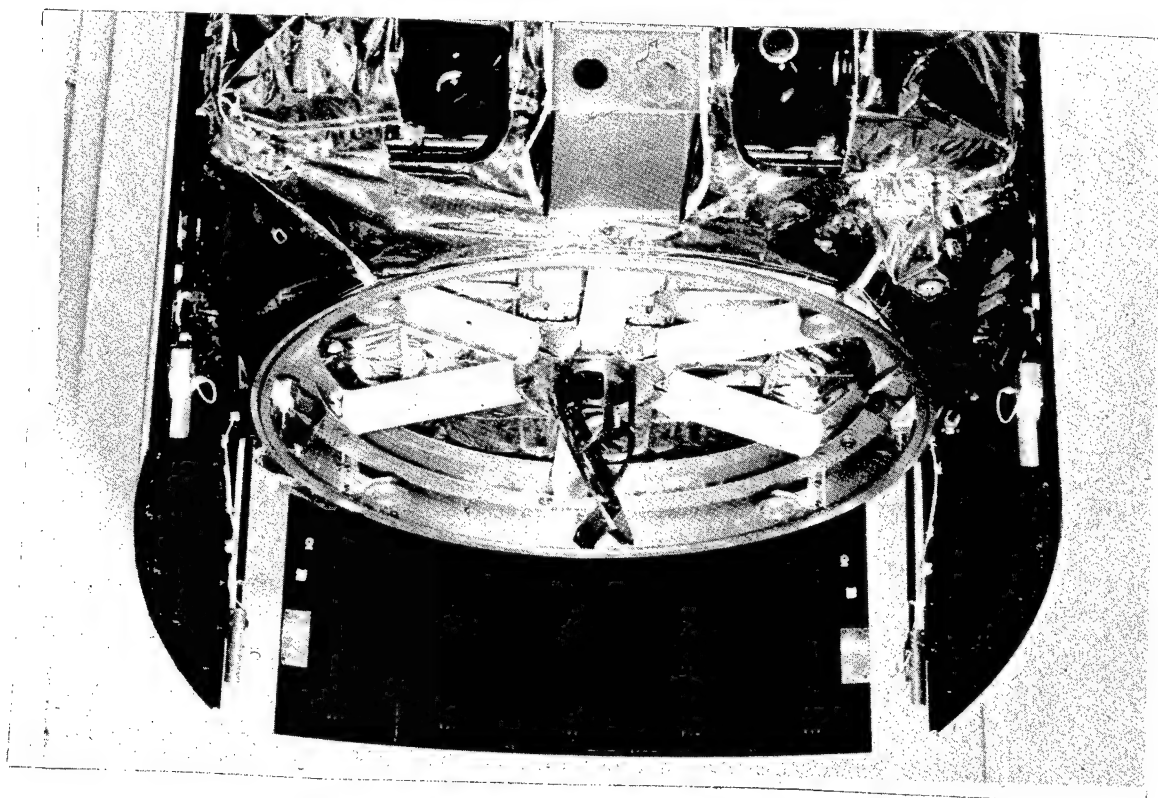
## Passive nutation damper

|                                |                     |
|--------------------------------|---------------------|
| Inner diameter of tube         | : 30 mm $\phi$      |
| Center diameter of tube        | : 1,100 mm $\phi$   |
| Sealed liquid                  | : Silicon oil (cst) |
| Nutation damping time constant | : 2.3 hours         |

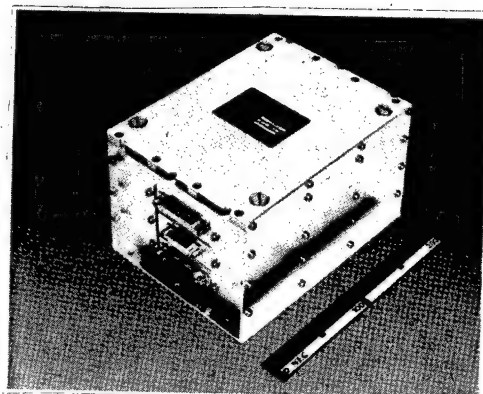


|  |  |
|--|--|
| Magnetic attitude control coil   | Magnetic momentum control coil   |
| Maximum rated magnetic moment: 50 ATm <sup>2</sup>                                   | Maximum rated magnetic moment: 20 ATm <sup>2</sup>                                   |
| Shape : 64cmx2.6cm $\phi$<br>(constant-current drive, duplex winding coil with core) | Shape : 49cmx1.9cm $\phi$<br>(constant-current drive, duplex winding coil with core) |

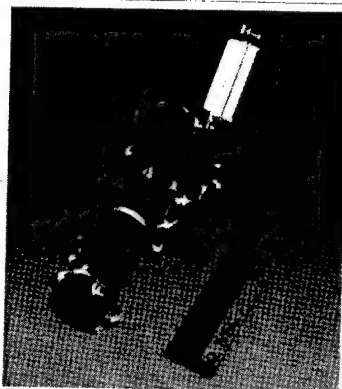
[Attitude Orbit Control System]



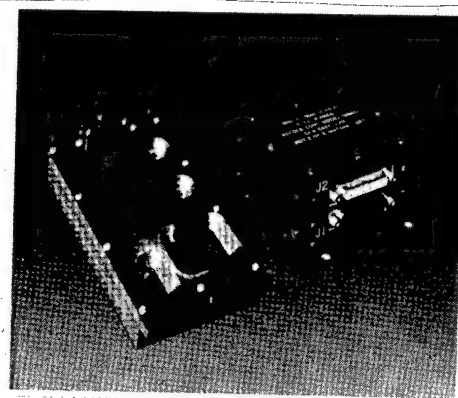
ITOS scan wheel assembly



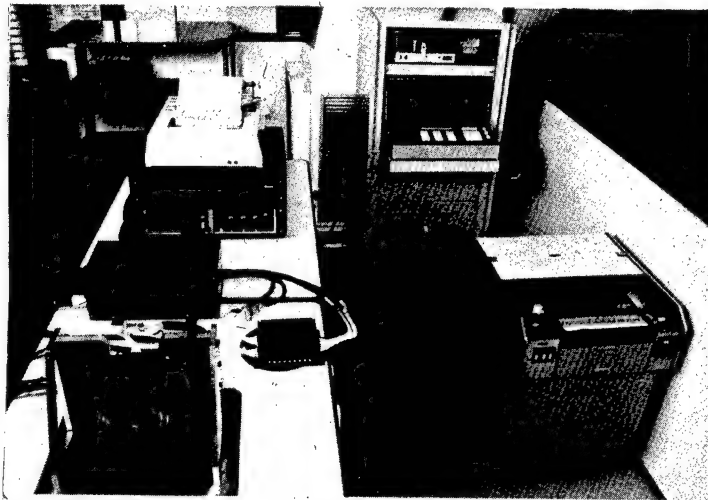
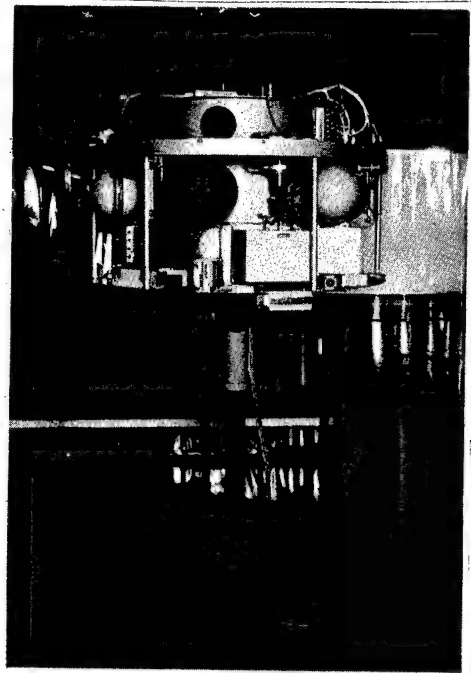
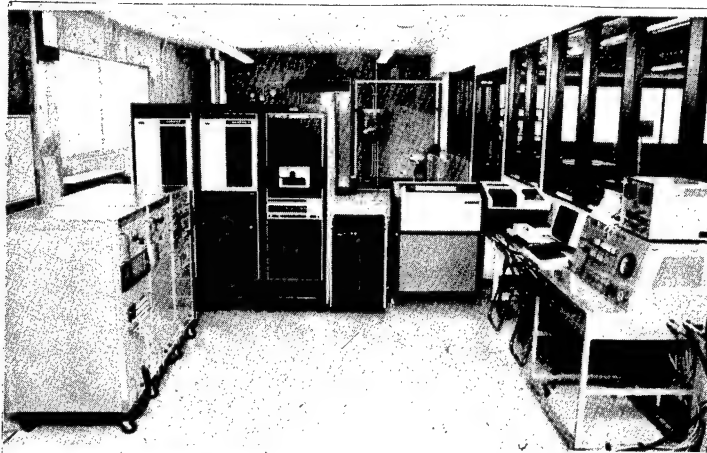
Electronic equipment to process [the data from] the terrestrial magnetism sensor



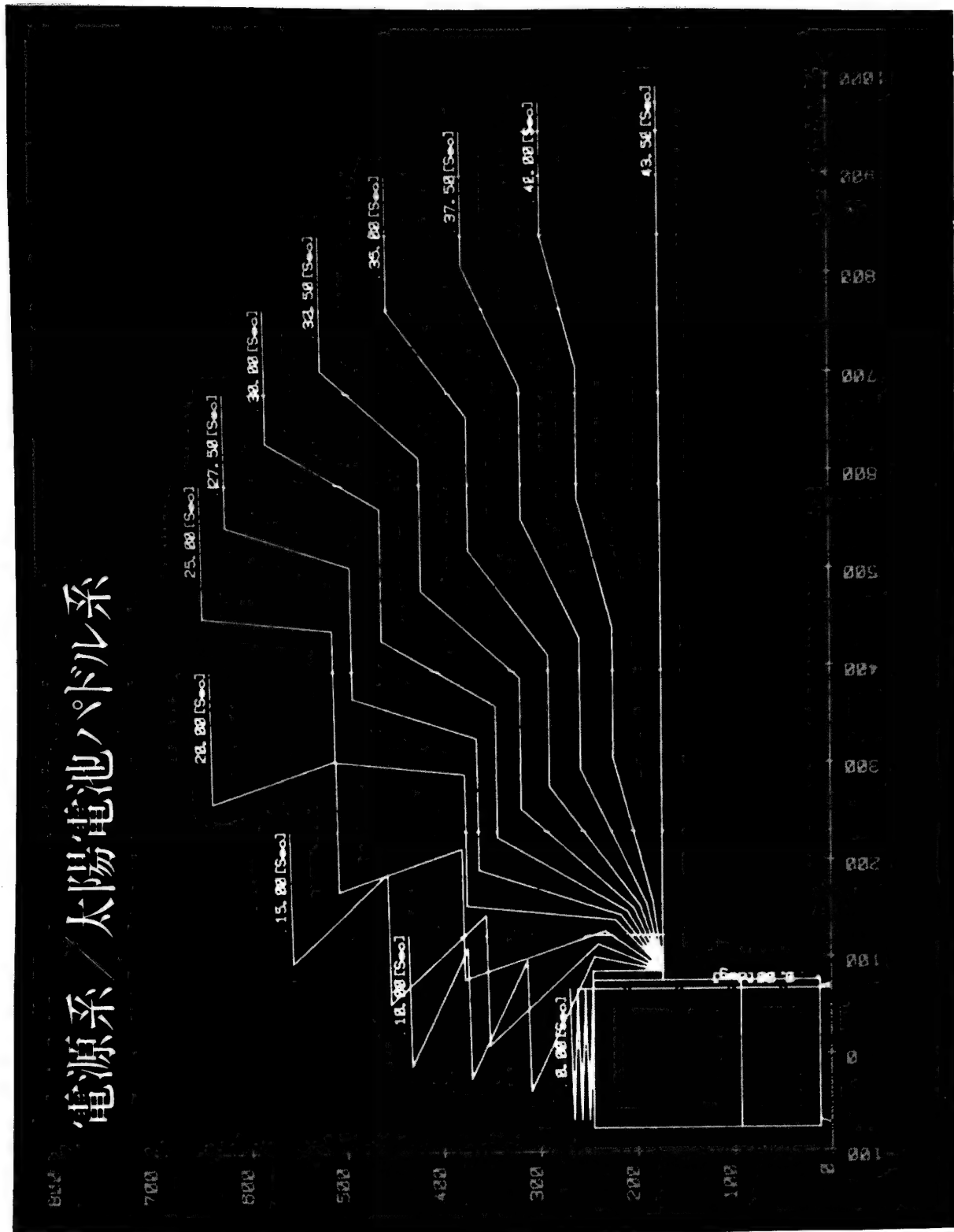
Terrestrial magnetism sensor



Sun sensor



Upper left : Dynamic simulator (computer section)  
 Lower left : Dynamic simulator (air bearing section)  
 Right : MS-T4 momentum wheel and its testing apparatus

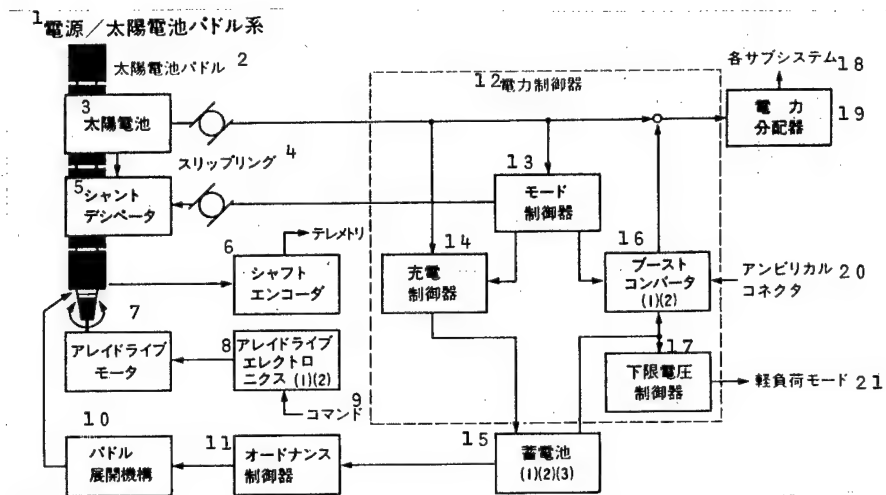


The power supply system provides uninterrupted electric power needed by the mission and bus equipment for 2 years during which the satellite performs its tasks. The electric power is generated by using the solar cells, and batteries are used when the satellite is in shadow.

To adapt to a solar synchronous orbit and to secure a field of vision for the mission equipment, the solar cell paddle has a single-sheet paddle configuration. The batteries consist of a 3-system parallel configuration. They are controlled by the charge regulator method, which has good electric power efficiency and bus voltage stability. For the shunt method, a sequence controlled through the partial shunt method, which enables a reduction of equivalent heat generation, is used. To decrease the number of power slip rings, the shunt dissipator was mounted on the paddle side, and the shunt resistance was mounted on the back side of the paddle to achieve better heat dissipation.

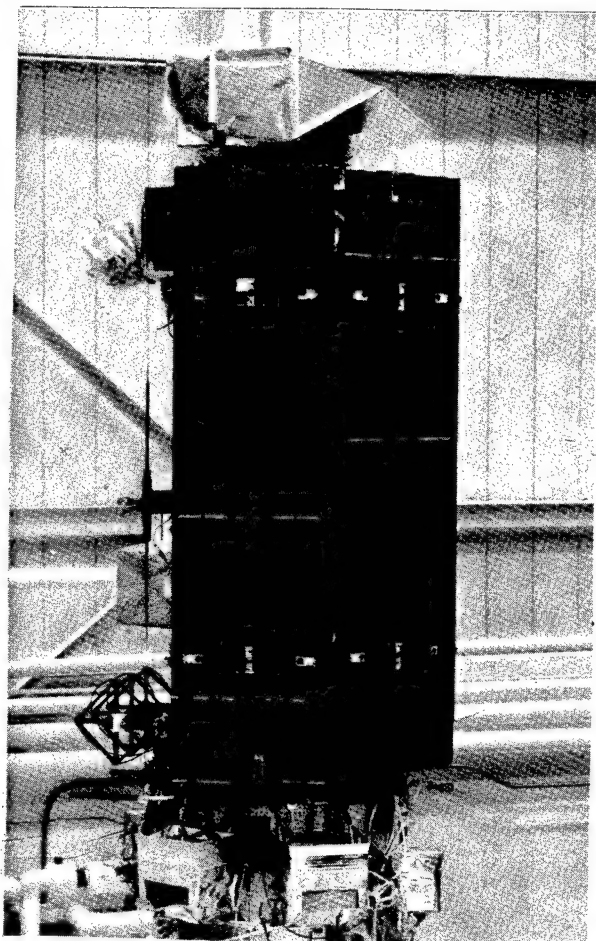
#### Power supply system data

|                           |   |
|---------------------------|---|
| Solar cell                | 2 cm x 2 cm N/P silicon solar battery cell, a total of 94 x 234 = 21,996 sheets. 0.3 mm glass cover<br>Generated power: BOL 670 watts, EOL 590 watts          |
| Battery                   | Square, sealed Ni-Cd secondary batteries<br>15 AH x 17 in series x 3 systems<br>Maximum discharge depth: at launch 34 percent,<br>during operation 16 percent |
| Power controller          | Charge mode/discharge mode/shunt mode: automatic switching<br>Stabilized voltage 29V $\pm$ 2 percent  |
| Shunt dissipator          | Partial shunt method<br>24 circuits sequential control<br>Maximum shunt processing capability: about 700 watts  |
| Boost converter           | More than 400 watts   |
| Ordinance control circuit | Current with extended paddle 30 A (20 ms)   |

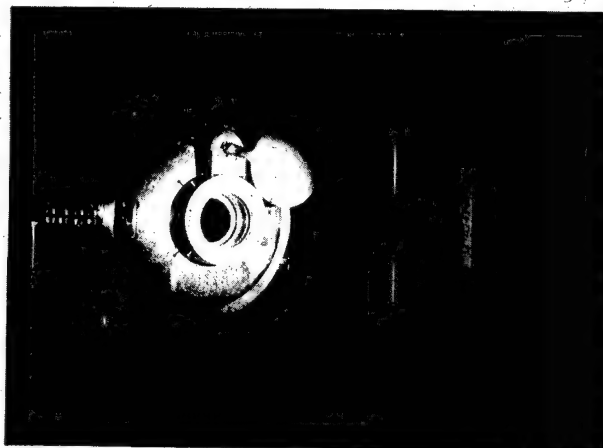
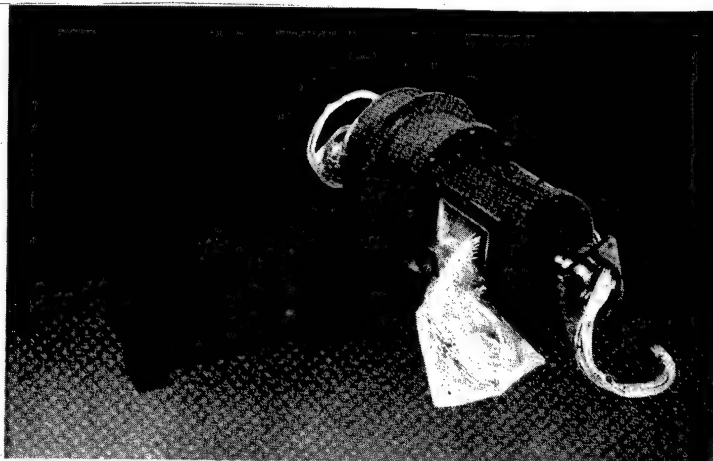


Key:

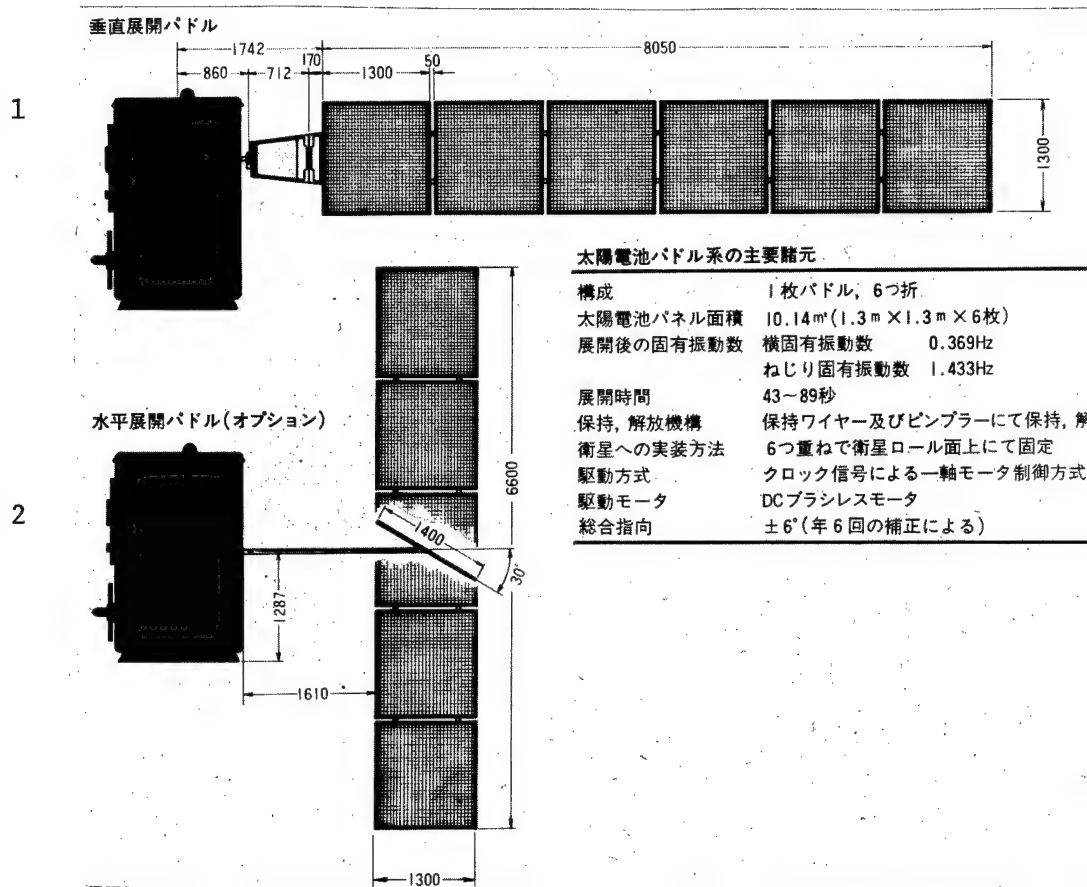
- |  |                                    |
|--|------------------------------------|
| 1. Power supply/solar cell paddle system | 11. Ordnance controller            |
| 2. Solar cell paddle                     | 12. Power controller               |
| 3. Solar cell                            | 13. Mode controller                |
| 4. Slip rings                            | 14. Charge controller              |
| 5. Shunt dissipator                      | 15. Batteries (1) (2) (3)          |
| 6. Shaft encoder                         | 16. Boost converters (1) (2)       |
| 7. Array drive motor                     | 17. Lower limit voltage controller |
| 8. Array drive electronics (1) (2)       | 18. Each subsystem                 |
| 9. Command                               | 19. Power distributor              |
| 10. Paddle extension mechanism           | 20. Umbilical connector            |
|  | 21. Light load mode                |
|  | 22. Telemetry                      |



TIROS-N solar cell paddle



Upper: Array drive motor and electronics  
Lower: Solar simulator



Key: 1. Vertically extended  
paddle

2. Horizontally extended  
paddle (optional)

#### Major data for the solar cell paddle system

|  |  |
|--|--|
| Configuration  | Single sheet paddle, folded six times                                |
| Area of the solar cell panel                             | 10.14 m <sup>2</sup> (1.3m x 1.3m x 6 sheets)                        |
| Characteristic frequency<br>after the paddle is extended | Lateral proper frequency 0.369 Hz<br>Twist proper frequency 1.433 Hz |
| Time required for extension                              | 43-89 seconds  |
| Retention and release<br>mechanisms                      | Retention wire and pimpler are used for<br>retention and release     |
| Mounting method on the<br>satellite                      | Folded six times and mounted on the satellite's<br>roll side         |
| Drive method   | Single axis motor control by clock signals                           |
| Drive motor  | DC brushless motor   |
| Combined directionality                                  | ±6° (through 6 adjustments per year)                                 |

## Airframe System



Space environment laboratory in which integration and testing of MOS-1 are carried out.

The airframe consists of a mission module, which houses mission equipment, and a bus module, which contains shared equipment. Each module uses an outer shell structure method that does not have a main frame.

- Design characteristics
- The frame was designed to make integration easier by dividing it into the mission and bus modules.
- Future expandability is guaranteed by adopting the module structure.
- The outer shell structure facilitates instrumentation and checkout and efficiently uses the space that is available for mounting [the instruments].

#### Satellite structure, major dimensions, and weight

|                |  |
|----------------|--|
| Dimensions     | 1.4m (length) x 1.5m (width) x 2.5m (height) |
| Mission module | 1.1m (length) x 1.5m (width) x 1.5m (height) |
| Bus module     | 1.4m (length) x 1.5m (width) x 1.0m (height) |
| Weight         |  |
| Mission module | 65.7 kg                                      |
| Bus module     | 54.3 kg                                      |
|                | <u>120.0 kg</u>                              |

#### Major structural materials

##### Mission module panel

30/40mm honeycomb sandwich structure  
 Surface panel made of high strength aluminum alloy  
 Core made of corrosion resistant aluminum alloy

##### Bus module panel

30/40mm honeycomb sandwich structure  
 Surface panel made of high strength aluminum alloy  
 Core made of corrosion resistant aluminum alloy

##### Adaptor ring

Machine processed  
 High strength, forged aluminum alloy

#### Results of structural analysis

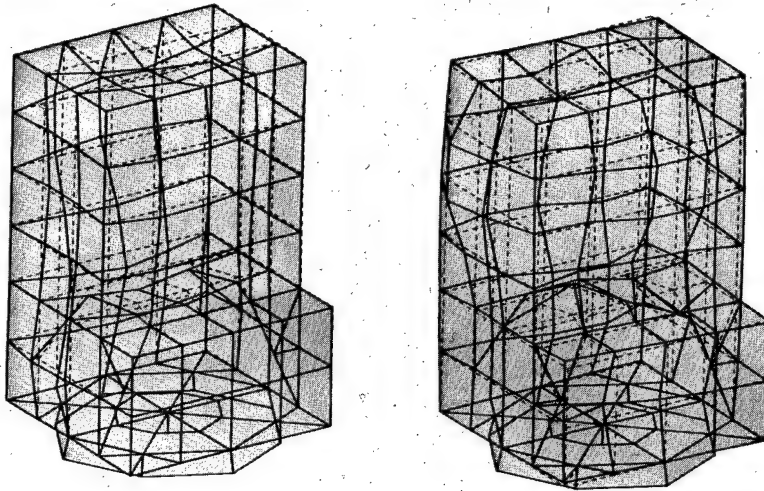
##### Proper frequency (at launch)

Thrust axis direction, primary 61 Hz  
 Lateral, primary 16 Hz

##### Proper frequency (in orbit) 0.37 Hz

##### Safety tolerance rate of major structural materials

Mission module earth panel 2.6  
 Mission module panel 3.4  
 Bus module base panel 1.7  
 Bus module panel 1.4  
 Adaptor ring 1.6



Key: [to page 29 diagram]

1. Composition of airframe system
2. Base panel
3. Adaptor ring
4. Sun panel
5. Space panel
6. Anti-earth panel
7. Earth panel
8. Tank panel
9. Velocity panel
10. Upper panel
11. Solar cell paddle

1

構体系 構成図

2

ベース パネル

3

アダプタ リング

4

サンパネル

5

スペース パネル

6

アンチアース パネル

7

アース パネル

8

タンク パネル

ベロシティ パネル

サン パネル

スペース パネル

5

7

6

アンチアース パネル

10

11

アッパー パネル

太陽電池 パネル

## Thermal Control System

The thermal control system is based on a passive method, but it uses some active modes (thermal louver and heater) as well. The satellite surface consists of two panels. One panel actively controls thermal conditions by making its surface dissipate heat efficiently, while the other panel restricts heat exchange with the outside by insulating its surface with thermal blankets. The main part of the thermal control panel is the pitch side, and the auxiliary parts are the yaw side and roll side.

The equipment in the bus system is mostly installed on the heat dissipation side of the thermal control panel, and the apparatus in the mission system that generates much heat is equipped with thermal louvers. The interior of the satellite is painted black to make the inside temperature of the satellite uniform. The gas jet system is equipped with a heater in order to prevent chilling. The temperature of the batteries is also controlled by a heater.

- Design characteristics
- Design is based on the passive type, which our company has much experience with, while the active type is also used to create an environment with safe temperatures.
- Operation is made much simpler by using thermal control elements which are driven and controlled on board.

### Thermal control system data

#### Electric power for heaters

Battery 22 watts

Gas jet system

(excluding the catalytic heater) 15 watts

#### Thermal louvers

0.25m x 0.3m 10 units

0.2 m x 0.22m 1 unit

0.4 m x 0.22m 1 unit

#### Passive heat dissipation surface

Total area About 13.7m<sup>2</sup>,  $\epsilon = 0.67$

#### Design temperatures

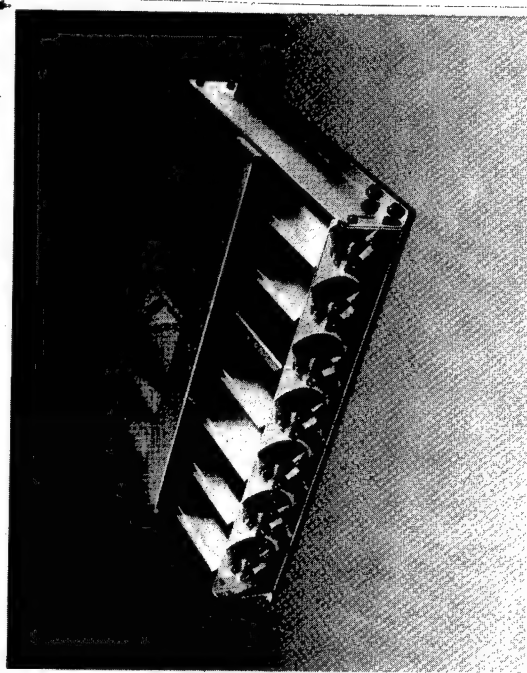
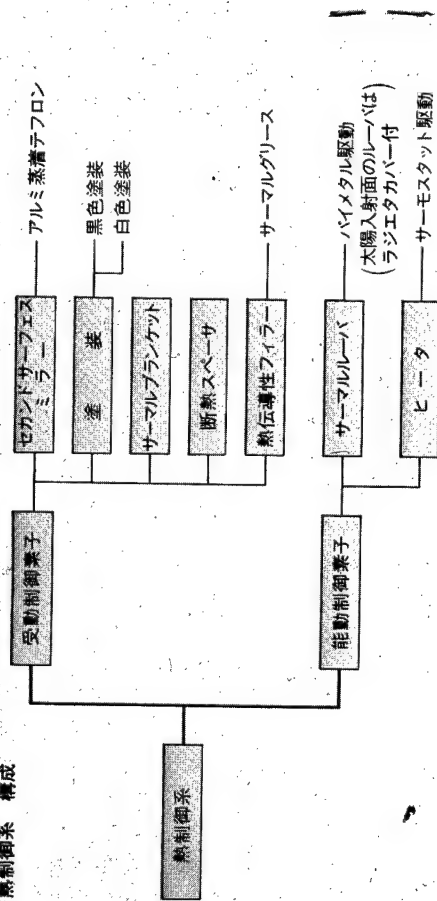
##### Margins for operating temperatures

Critical apparatus 0°C (Required: 0°C or higher)

Other apparatus 15°C (Required: 15°C or higher)



熱制御系 構成



Test sample of a thermal louver

12-17

5-11

3-4

1-2

Key: 1. Composition of the thermal control system

2. Thermal control system

3. Passive control elements

4. Active control elements

5. Second surface mirror

6. Painting

7. Thermal blanket

8. Insulation spacer

9. Heat conductive filler

10. Thermal louvers

11. Heaters

12. Aluminum evaporated teflon

13. Painted black

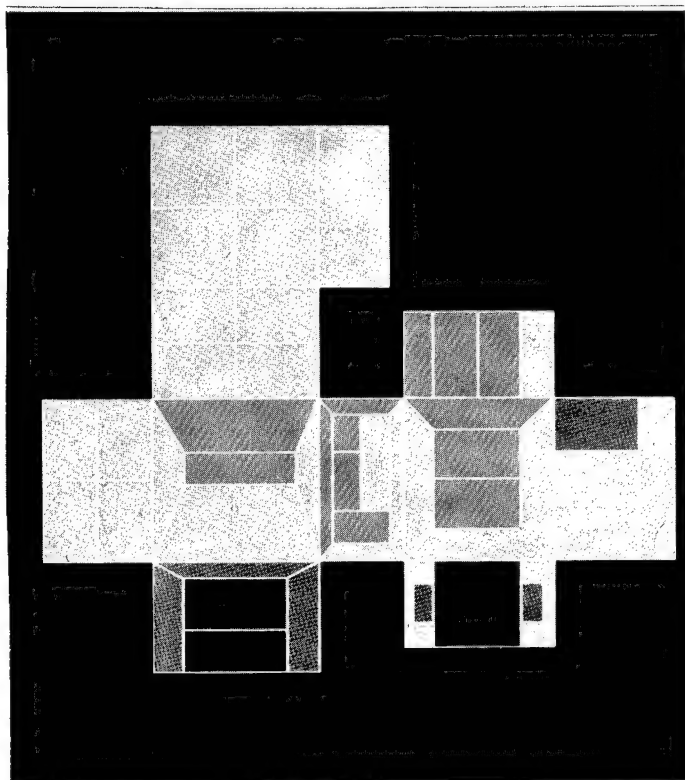
14. Painted white

15. Thermal grease

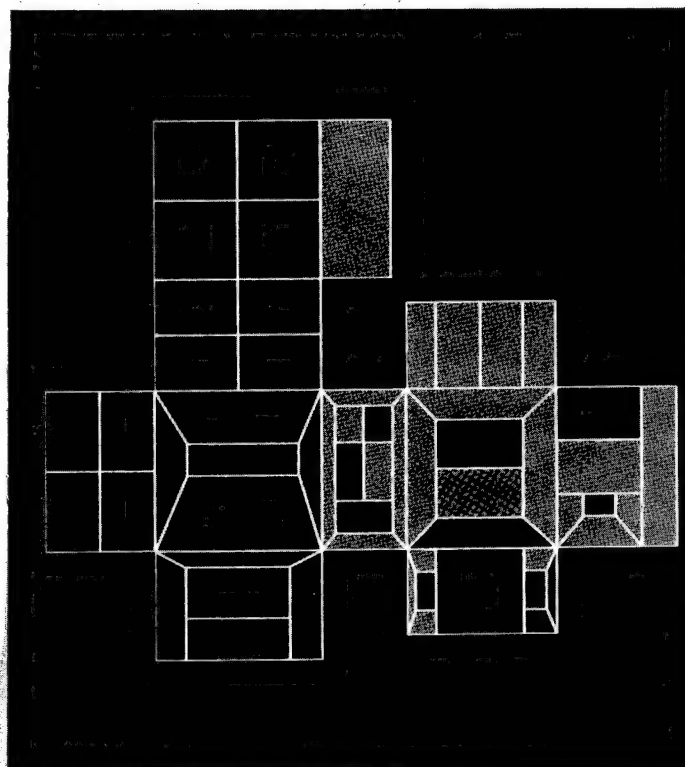
16. Driven by bimetal

(the louver that faces the sun has a radiator cover)

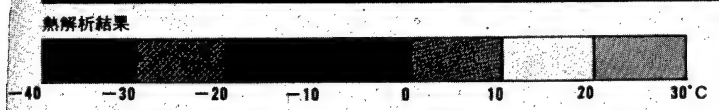
17. Driven by thermostats



Anticipated  
temperatures  
(upper limit)



Anticipated  
temperatures  
(lower limit)



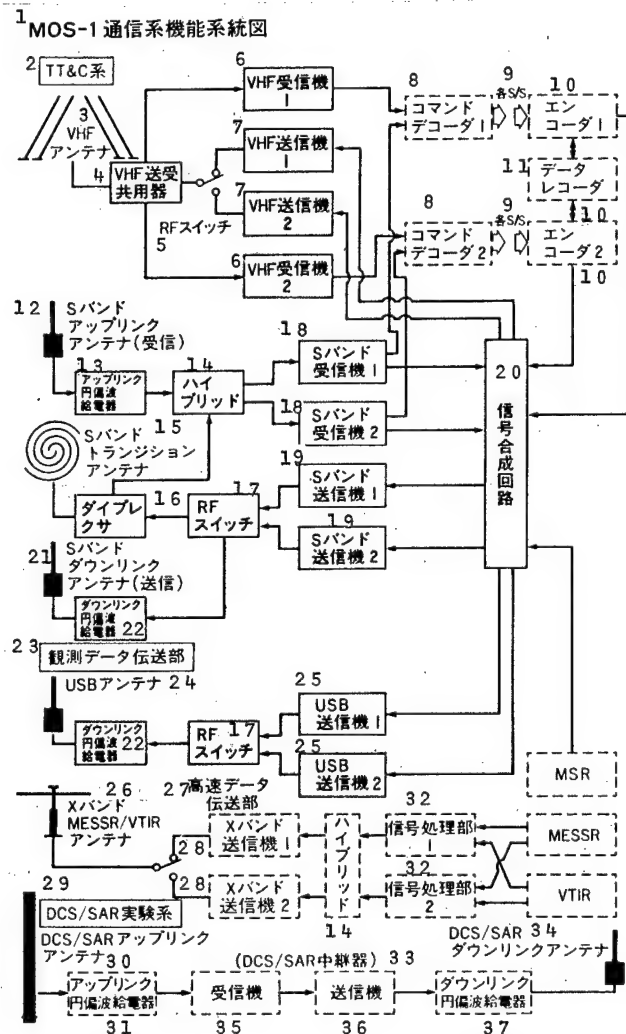
Color chart for the  
thermal analysis results

## Communication System/Antenna System

The communication subsystem consists of telemetry, a command system, an observation data transmission system, and a data collection system/search and rescue experimental system.

### ● Design characteristics

- TT&C system used methods that were also used on the ETS-III satellite as much as possible.
- The S-band range finding can be carried out by two stations simultaneously.
- The USB and X-band are used for the transmission of observed data to allow reception by existing foreign stations.
- A remodulation type has been adopted for DCS/SAR relay in consideration of future on-board data processing.
- Mutual interference between many frequencies are minimized.

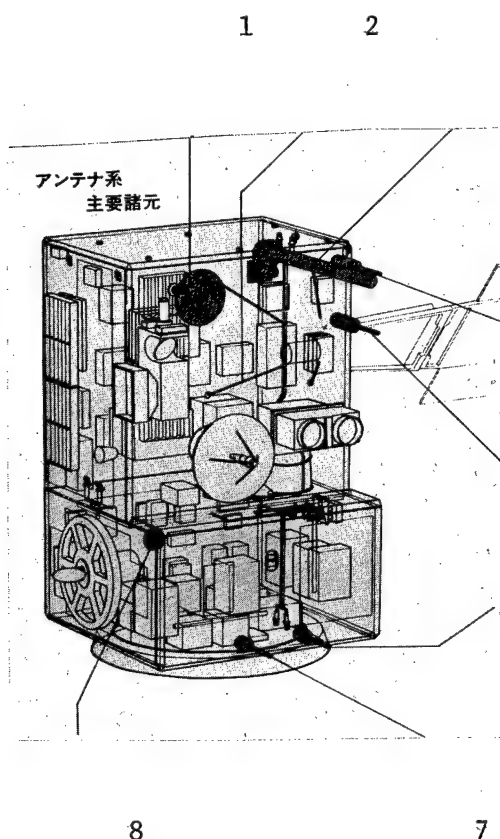


[key on next page]

Key: [to page 34 diagram]

1. MOS-1 communication system function chart
2. TT&C system
3. VHF antenna
4. Shared equipment for VHF transmitter and receiver
5. RF switch
6. VHF receiver
7. VHF transmitter
8. Command decoder
9. Each S/S
10. Encoder
11. Data recorder
12. S-band up-link antenna (for reception)
13. Up-link, circularly polarized wave feeder
14. Hybrid
15. S-band transition antenna
16. Diplexer
17. RF switch
18. S-band receiver
19. S-band transmitter
20. Signal synthesizing circuit
21. S-band down-link antenna (for transmission)
22. Down-link, circularly polarized wave feeder
23. Observation data transmission section
24. USB antenna
25. USB transmitter
26. X-band MESSR/VTIR antenna
27. High speed data transmission section
28. X-band transmitter
29. DCS/SAR experimental system
30. DCS/SAR up-link antenna
31. Up-link, circularly polarized wave feeder
32. Signal processing section
33. DCS/SAR relay
34. DCS/SAR down-link antenna
35. Receiver
36. Transmitter
37. Down-link, circularly polarized wave feeder

# Major Data for the Antenna System



Key:

## 1. X-band antenna

|              |                                 |
|--------------|---------------------------------|
| Type         | Turnstyle                       |
| Frequency    | 8.4 GHz band                    |
| Polarization | Right circularly polarized wave |

## 4 2. VHF antenna

|              |  |
|--------------|--|
| Type         | Monopole   |
| Frequency    | 136 MHz band (down link)<br>148 MHz band (up link) |
| Polarization | Right and left circularly polarized waves          |

## 6 3. UHF antenna for DCS/SAR up-link

|              |                                 |
|--------------|---------------------------------|
| Type         | Quadrifilar helical             |
| Frequency    | 406 MHz band                    |
| Polarization | Right circularly polarized wave |

## 4. USB antenna

|              |                                 |
|--------------|---------------------------------|
| Type         | Quadrifilar helical             |
| Frequency    | 2.2 GHz                         |
| Polarization | Right circularly polarized wave |

## 5. L-band antenna for DCS/SAR down-link

|              |                                 |
|--------------|---------------------------------|
| Type         | Quadrifilar helical             |
| Frequency    | 1,543 MHz                       |
| Polarization | Right circularly polarized wave |

## 6. S-band down-link antenna

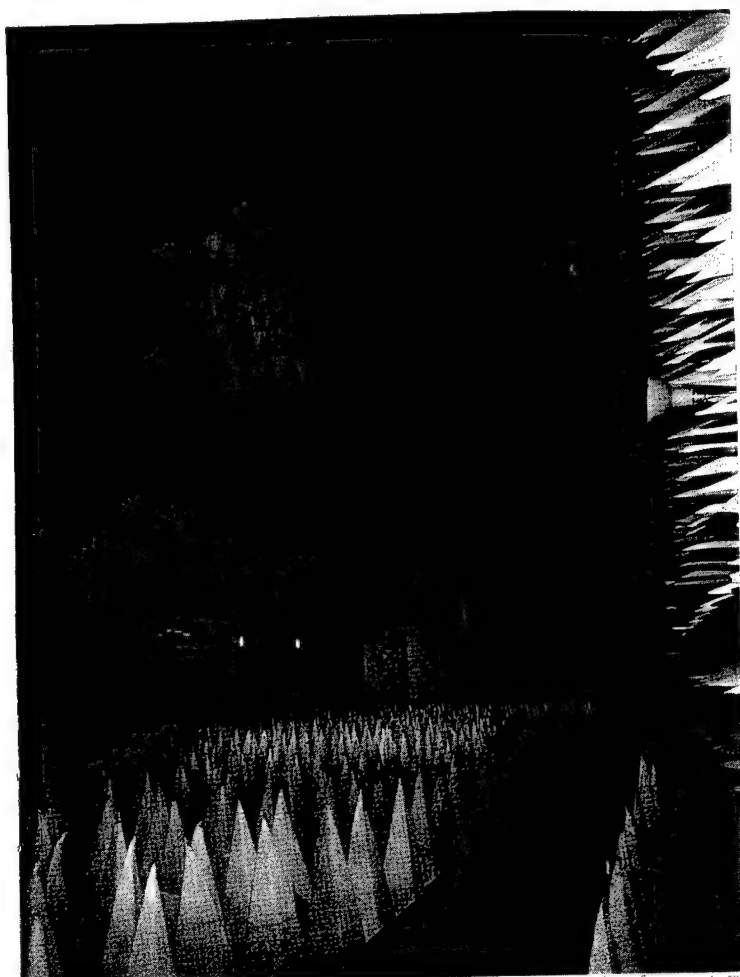
|              |                                 |
|--------------|---------------------------------|
| Type         | Quadrifilar helical             |
| Frequency    | 1.7 GHz band                    |
| Polarization | Right circularly polarized wave |

## 7. S-band up-link antenna

|              |                                 |
|--------------|---------------------------------|
| Type         | Quadrifilar helical             |
| Frequency    | 2.1 GHz band                    |
| Polarization | Right circularly polarized wave |

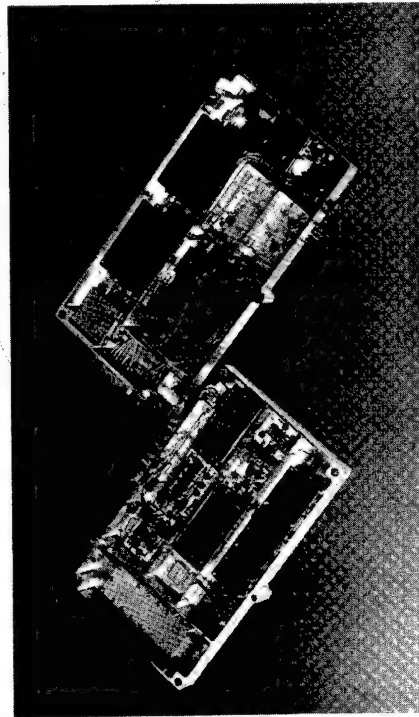
## 8. S-band transition antenna

|              |  |
|--------------|--|
| Type         | Spiral                                 |
| Frequency    | 1.7 GHz (down-link); 2.1 GHz (up-link) |
| Polarization | Right circularly polarized wave        |

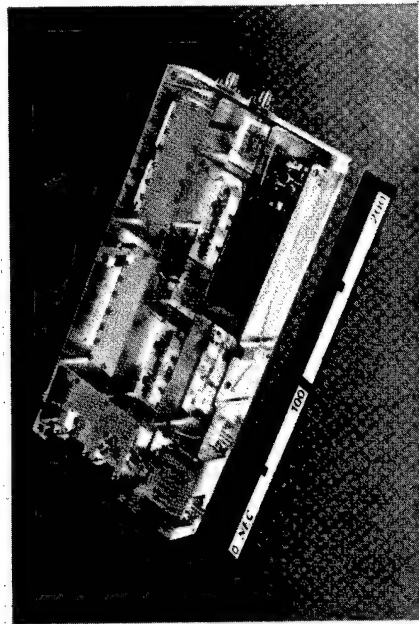


Radio wave dark room

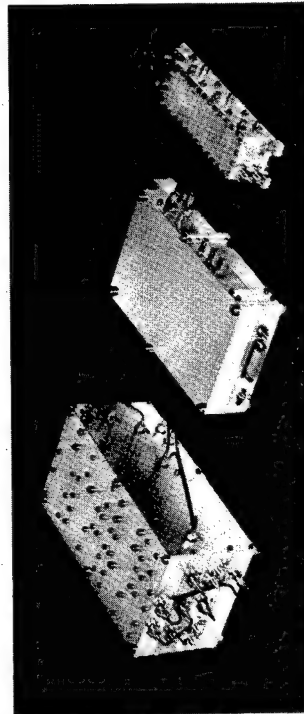
USB transmitter



S-band receiver



S-band transmitter, receiver and diplexer



Quadrifilar helical antenna



# Data for Communication System

## TT&C system

### Telemetry

|                        | VHF   | S-band                    | USB        |
|------------------------|---|---------------------------|------------|
| Modulation method      | PCM-PM                                      | PCM-FM-PM<br>PCM-PM*      | PCM-FM-PM  |
| Carrier wave frequency | 136.11 MHz                                  | 1705.0 MHz                | 2280.0 MHz |
| Modulation index       | 1.0 radian                                  | 0.35 radian<br>0.7 radian | 0.5 radian |
| Transmission output    | 1.0 W                                       | 0.3 W                     | 0.1 W      |
| Bit rate               | 1,024 bps (real time), 26.624k bps (replay) |                           |            |
| Code type              | Split phase level                           |                           |            |
| Subcarrier frequency   | 87.5 KHz                                    |                           |            |
| Command                | *(replay)                                   |                           |            |

|                        | VHF                      | S-band        |
|------------------------|--------------------------|---------------|
| Modulation method      | PCM-FSK/AM-PM            | PCM-FSK/AM-PM |
| Carrier wave frequency | 148.27 MHz               | 2115.6 MHz    |
| Modulation index       | 0.9 radian               | 0.4 radian    |
| Noise index            | 8.0 dB                   | 3.0 dB        |
| Bit rate               | 128 bps                  |               |
| FSK frequency          | "1" 8600 Hz, "0" 7400 Hz |               |
| AM Modulation index    | 50 percent               |               |

### Ranging

|                        | Up-link   | Down-link        |
|------------------------|---|------------------|
| R&RR method            | PN code ranging tone (distance)<br>Two-way doppler (rate of change in distance)<br>Simultaneous measurement from two different stations is possible |                  |
| Modulation method      | PRN-PSK-PM  | PRN-PSK-PM-PM    |
| Carrier wave frequency | 2115.6 MHz, 2117.8MHz   | 1705.0 MHz       |
| Modulation index       | 1.0 radian  | 0.35 radian/CH   |
| Subcarrier frequency   | --  | 1.4 MHz, 3.6 MHz |
| PN code bit rate       | 125 kbps  |                  |
| PSK frequency          | 500 KHz   |                  |

### Observation data transmission system

#### MSR/MESSR/VTIR

|                        | USB(MSR)     | X-band (MESSR/VTIR) |
|------------------------|--------------|---------------------|
| Modulation method      | PCM-PM       | PCM-MSK             |
| Carrier wave frequency | 2286.0 MHz   | 8400 MHz            |
| Modulation index       | 0.7 radian   | --                  |
| Transmission output    | 0.1 W        | 4.0 W               |
| Bit rate               | 2000 bps     | 8.78M bps           |
| Code type              | BIφ-L serial | NRZ-M               |

[continued]

# DCS/SAR experiment system

## DCS/SAR relay

|                        | Up-link           | Down-link  |
|------------------------|-------------------|------------|
| Relay method           | Remodulation type |            |
| Modulation method      | PCM-PM            | PCM-PM-PM  |
| Carrier wave frequency | 406.0 MHz         | 1543.0 MHz |
| Modulation index       | 1.2 radian        | 1.0 radian |
| Subcarrier frequency   | --                | 200 KHz    |
| Bit rate               | 128 bps           |            |
| Code type              | Biphase level     |            |

## Telemetry/Command System

The telemetry/command system consists of a telemetry encoder, a remote telemetry unit, a command decoder, and a data recorder. We used the same methods as those used on EST-III as much as possible. The data recorder is on board in order to receive telemetry data [collected] in invisible regions. For commands, we use discrete magnitude and stored commands. It is possible to operate the satellite through a single station in Japan.

Major functions of the telemetry and command system are listed below.

- Functions of the telemetry system
  - Telemetry signals are encoded and transmitted through the S-band, USB, or VHF band.
  - To monitor the operation of the satellite in the regions which cannot be observed [from Japan] directly, telemetry signals are stored in a data recorder, and then they are replayed at high speed when the satellite is visible from the ground station.
- Functions of the command system
  - Switching and control of satellite operations are carried out by receiving command signals through the S-band and VHF band.
  - The command operations can provide real time control and delayed control through timers.

### Major data for telemetry/encoder system

#### Data format

|               |                        |
|---------------|------------------------|
| 1 minor frame | 128 words (per second) |
| 1 major frame | 8 minor frames         |
| 1 word length | 8 bits                 |
| Frame cycle   | 24 bits                |
| Bit rate      | 1,024 bps              |

#### Input

|                       |   |
|-----------------------|---|
| Analog input          | 279 CH 0-5 V {254 CH (1/8), 25 CH (1/1)}        |
| Serial digital input  | 30 CH {2 CH (1/8), 28 CH (1/1)} "1" 5 V, "0" 0V |
| Bilevel digital input | 165 CH "1" 5 V "0" 0V                           |

### Major data for the data recorder

|                     |  |
|---------------------|--|
| Data input channel  | 1 channel (2 tracks)                             |
| Recording time      | 105 minutes Min [minimum?] (105 minutes/2/track) |
| Replay time         | 4 minutes Min (2 minutes/track)                  |
| Replay/record ratio | 26/1   |
| Recording data      | 1,024 bps Biφ-L                                  |
| Replaying data      | 26,624 bps Biφ-L                                 |

# Major data for the command system

|                |   |
|----------------|---|
| Bit rate       | 1 channel (2 track)                               |
| Command format | Type I Discrete commands                          |
|                | Type II Discrete commands (without verification)  |
|                | Type III Magnitude commands                       |
|                | Type IV Magnitude commands (without verification) |
|                | Type V Stored commands                            |

## Word configuration

|                         |         |
|-------------------------|---------|
| Command word length     | 8 bits  |
| Magnitude word length   | 14 bits |
| Synchronous word length | 19 bits |
| Satellite address       | 7 bits  |

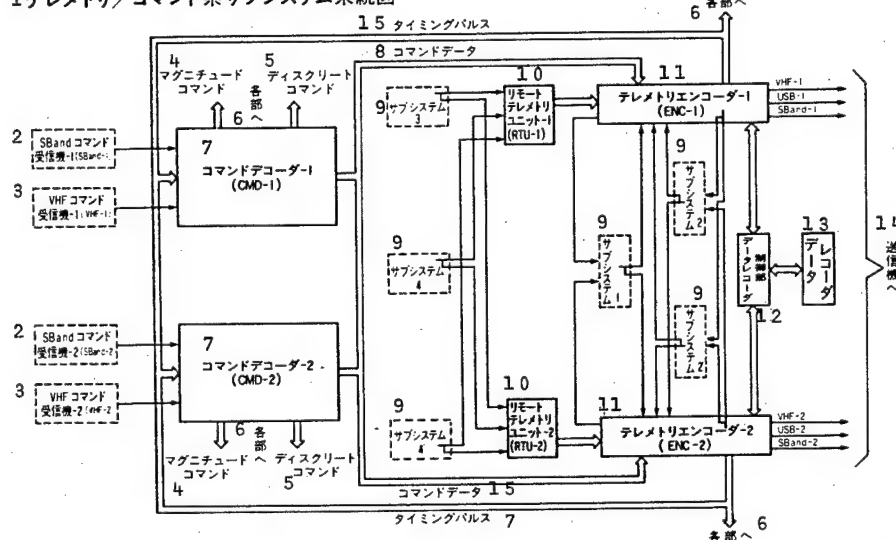
## Real time commands

|                    |           |                               |
|--------------------|-----------|-------------------------------|
| Discrete commands  | 254 (MAX) | <All "0", excluding "1" code> |
| Magnitude commands | 32 (MAX)  |                               |

## Stored commands

|   |            |
|---|------------|
| Discrete commands                       | 16 (MAX)   |
| Maximum delay time in command execution | 18.2 hours |

1 テレメトリ/コマンド系サブシステム系統図



## Key:

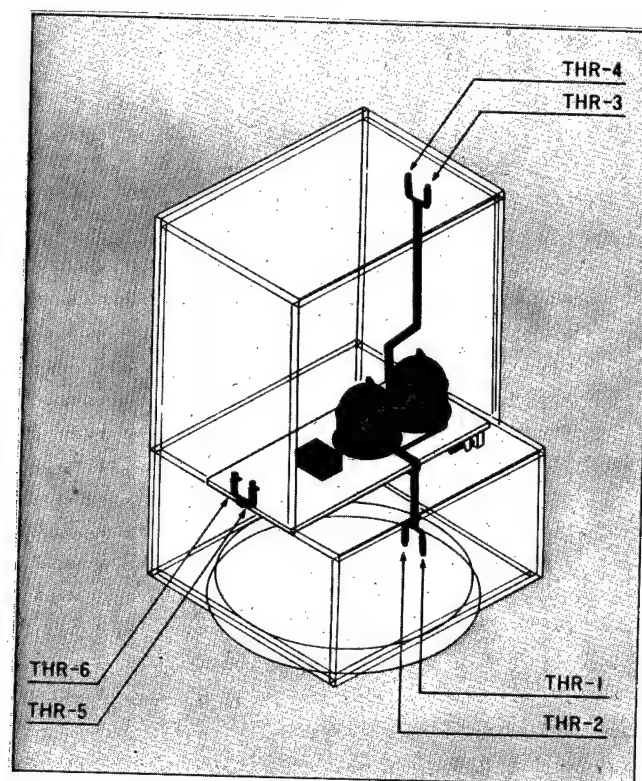
- |  |                                   |
|--|-----------------------------------|
| 1. Telemetry/command system subsystems chart | 8. Command data                   |
| 2. S-band command receiver                   | 9. Subsystem                      |
| 3. VHF command receiver                      | 10. Remote telemetry unit         |
| 4. Magnitude command                         | 11. Telemetry encoder             |
| 5. Discrete command                          | 12. Data recorder control section |
| 6. To various sections                       | 13. Data recorder                 |
| 7. Command decoder                           | 14. To transmitter                |
|  | 15. Timing pulse                  |

## Gas Jet System

The gas jet system consists of two propellant tanks, six thrusters, four filling and draining valves, two filters, four shutoff valves, and piping. This system performs the following functions.

- Orbital correction to achieve solar synchronous orbit after the satellite has been inserted into its initial orbit.
- Maintenance of the solar synchronous orbit during the mission period.

In order to facilitate the installation and integration of the gas jet system to the satellite, major equipment in the system has been concentrated on the bus equipment side and has been formed into modular subsystems. Also, to minimize shifting of the center of gravity as the propellant is spent, the fuel tank is installed over the center of gravity. The thrusters are arranged to remove plume impingement and sensor contamination. Furthermore, to avoid external disturbance to the satellite's attitude, the thrust axis of each thruster passes through the center of gravity of the satellite.



## Major data for the gas jet system

### Orbit control

Control inside the orbital plane

± roll direction 2N

THR - (1,2);(3,4)

Control outside the orbital plane

- pitch direction 2N

THR - (5,6)

### Propellant tanks

Type

Titanium alloy, spherical, all welded,  
contains bladder, polar mount type

Capacity

9.8 kg

Number

Two tanks

### Thruster

Type

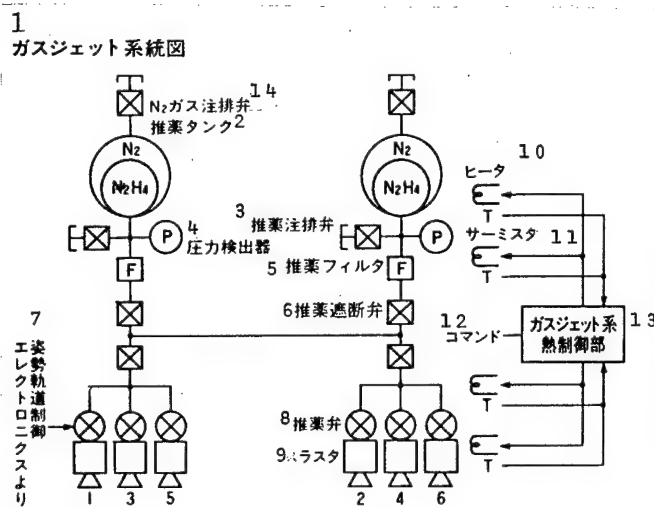
IN thruster, unit coupled with propellant

Catalysis

Shell 405

Number

Six units

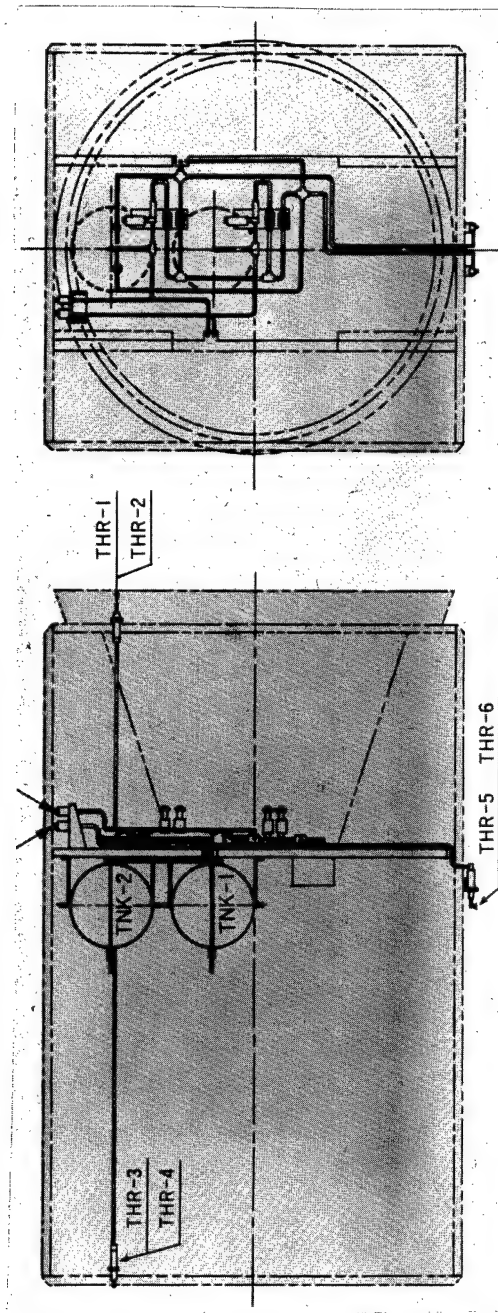


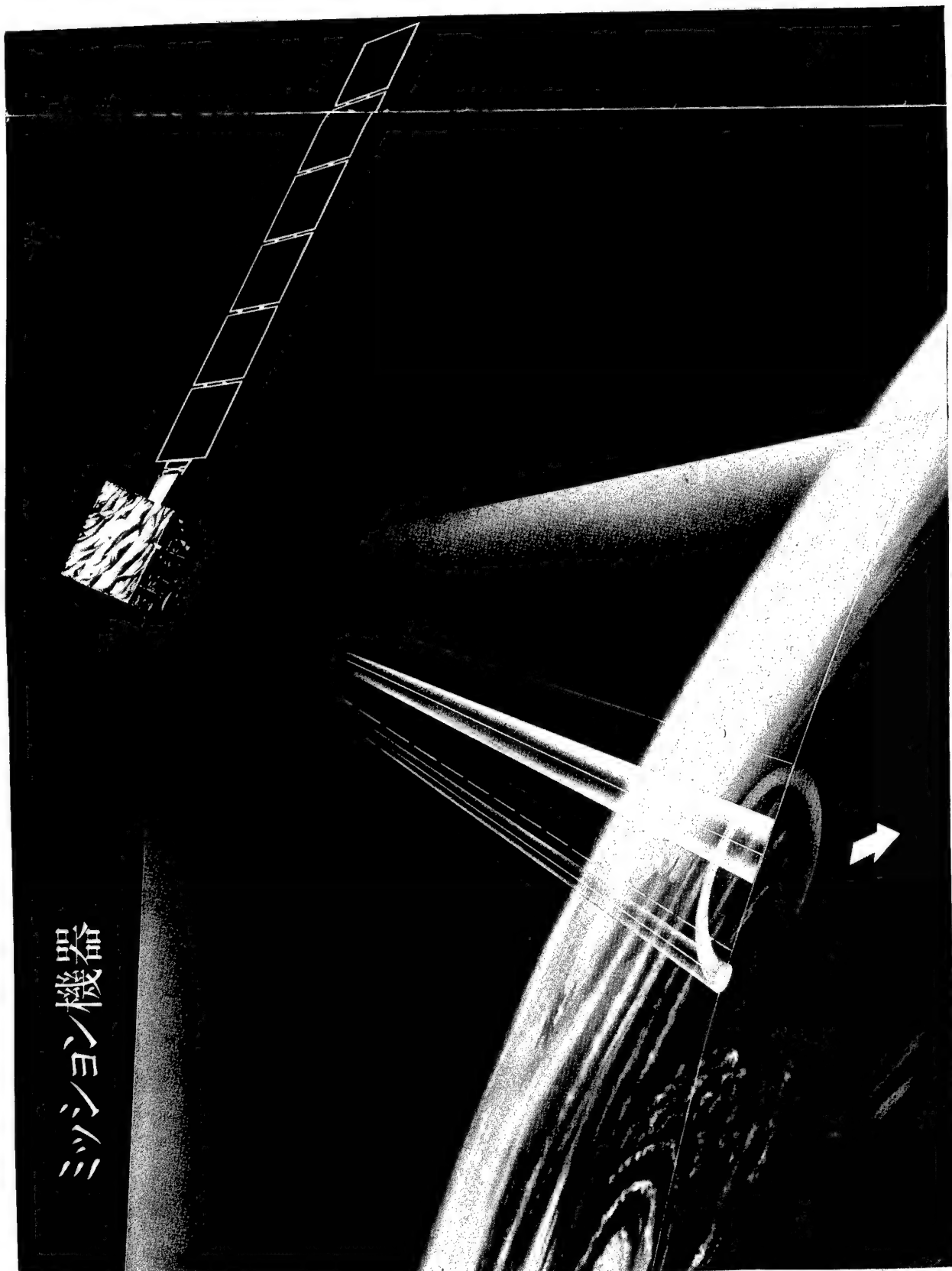
### Key:

- |  |   |
|--|---|
| 1. Gas jet system chart                                      | 8. Propellant valves                              |
| 2. Propellant tank   | 9. Thrusters                                      |
| 3. Propellant filling and draining valve                     | 10. Heater  |
| 4. Pressure detector   | 11. Thermister                                    |
| 5. Propellant filter valve                                   | 12. Command                                       |
| 6. Propellant shutoff valve                                  | 13. Gas jet system heat control section           |
| 7. Attitude orbit control signals from electronic [circuits] | 14. N <sub>2</sub> gas filling and draining valve |

N<sub>2</sub> gas filling and  
draining valve

N<sub>2</sub>H<sub>4</sub> propellant filling and  
draining valve





ミッシェン機器

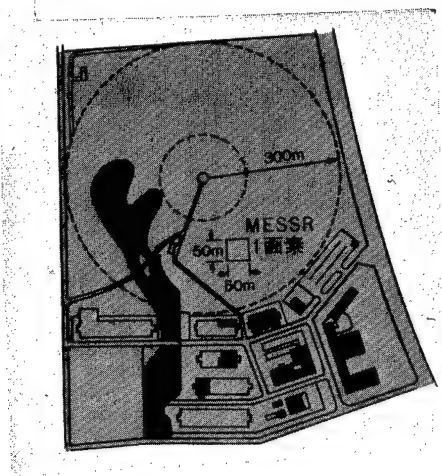
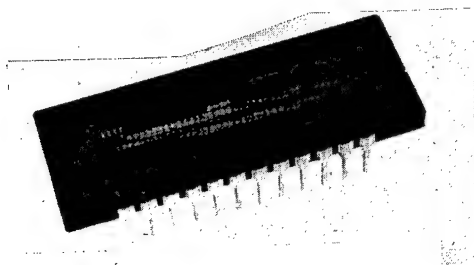
- Visible near-infrared radiometer

The visible near-infrared radiometer (MESSR) maps light reflected from the ground and sea surfaces in four colors between visible light and near-infrared, and it gathers maritime information such as sea surface pollution and water color. A CCD sensor with 2,048 elements is used to obtain two-dimensional images by using electrical scanning and orbital motion.

The scanning width on the ground is about 100 km, and one image element corresponds to about 50 m x 50 m on the ground. The processed digital signals are transmitted by the high speed data transmission section at the rate of 8.78 Mbit/sec. The data from the visible thermal infrared radiometer are multiplexed in the MESSR signal processing section. MESSR signals are transmitted in the X-band, similar to the frequency planned for Landsat-D.

- Visible thermal infrared radiometer

The purpose of the visible thermal infrared radiometer (VTIR) is to collect data on cloud and sea surface temperatures. It maps the images of land and sea with visible and thermal infrared wavelengths. For this purpose, VTIR uses one visible band and three infrared bands and rotates a scanning mirror by a mechanical rotating scanning method. The collected data are transmitted after they are multiplexed onto the MESSR signals.



⇐ Image elements

#### Data for MESSR

Scanning method

Detector

Instantaneous field of vision

Scanning width

Scanning time

Observation wavelength

Number of elements

Operating conditions

Electronic scanning

CCD array

54.5  $\mu$ rad

102 km

7.61m sec

Band 1 0.51-0.59 Band 3 0.72-0.8

2 0.64-0.72 Band 4 0.8-1.1

Each band 0248

Alternating operations of two optical systems

#### Data for VTIR

|  |   |
|--|---|
| Scanning method                          | Mechanical rotation scanning method                                       |
| Instantaneous field of vision            | 1 m rad (Visible [wavelength])<br>3 m rad (Thermal [infrared wavelength]) |
| Scanning width                           | 1,500 km  |
| Scanning time                            | 0.137 sec (one rotation)  |
| Observation wavelength ( $\mu\text{m}$ ) | 0.5-0.7<br>6.0-7.0<br>10.5-11.5<br>11.5-12.5                              |

#### ● Microwave radiometer

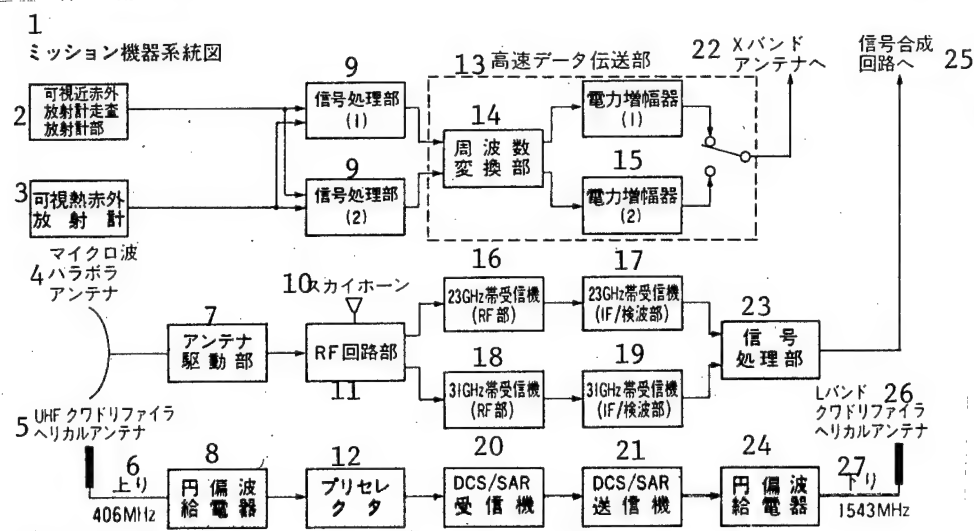
The microwave radiometer (MSR) maps images of land and sea with microwave band to acquire data on the amount of water vapor on the ocean surface and in the atmosphere, the amount of water, and sea ice. MSR uses two microwave bands for this purpose, and rotates an antenna by the mechanical rotation scanning method.

#### Data for the microwave radiometer

|                        |  |
|------------------------|--|
| Scanning method        | Mechanical rotation scanning method  |
| Beam width             | 2.4° Lower than [the indicated angles]<br>(23 GHz)<br>1.8° Lower than [the indicated angles]<br>(31 GHz) |
| Scanning width         | 320 km   |
| Scanning time          | 3.2 sec (one rotation)   |
| Observation frequency  | 23.8 GHz<br>31.4 GHz   |
| Temperature resolution | 1°K (23 GHz)<br>3°K (31 GHz) (Estimated values)  |

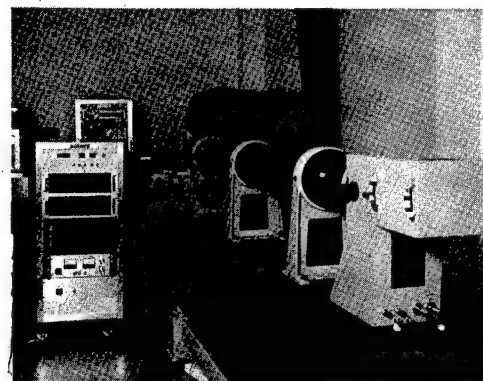
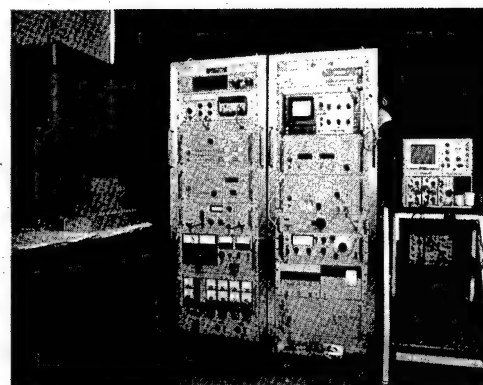
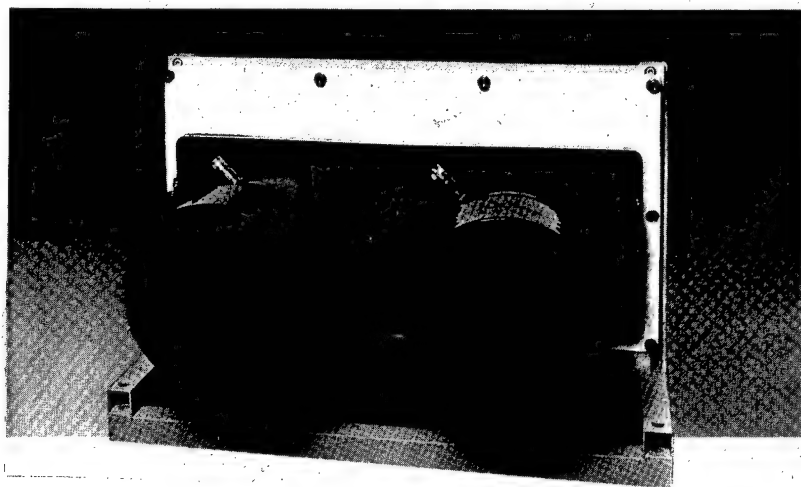
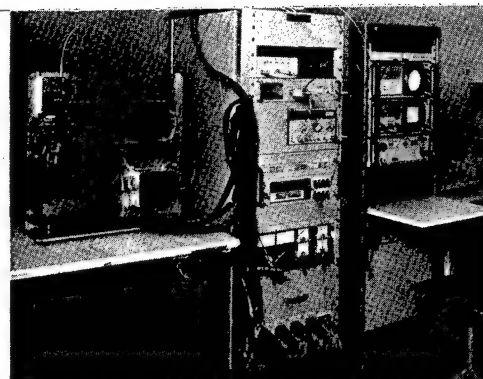
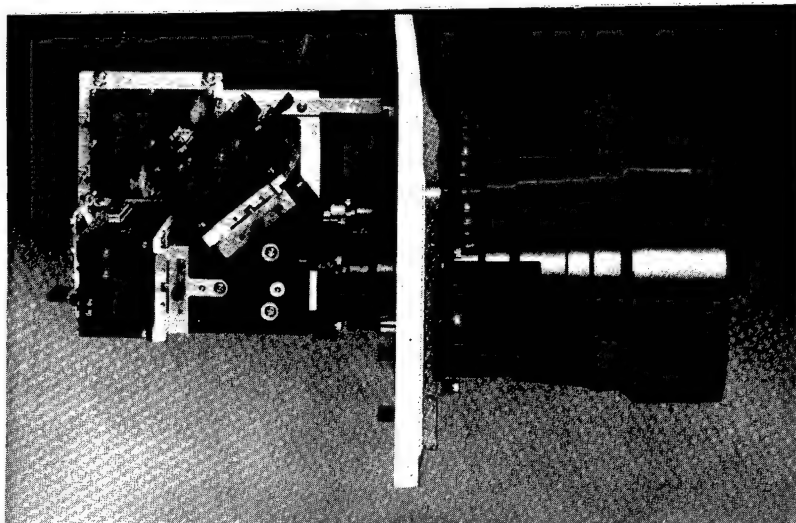
#### ● DCS/SAR relay

The DCS/SAR relay receives UHF band signals from a ground station and reemits them in the L band. Basic experiments, such as determining the location of an object on the ground using the Doppler effect, are carried out using this relay.



Key:

1. Mission equipment charge
2. Visible near-infrared radiometer scanning radiometer section
3. Visible thermal infrared radiometer
4. Microwave parabola antenna
5. UHF quadrifilar helical antenna
6. Up[-link]
7. Antenna driver section
8. Circularly polarized wave feeder
9. Signal processing section
10. Sky horn
11. RF circuit section
12. Preselector
13. High speed data transmission section
14. Frequency converter section
15. Power amplifiers
16. 23 GHz band receiver (RF section)
17. 23 GHz band receiver (IF/detector section)
18. 31 GHz band receiver (RF section)
19. 31 GHz band receiver (IF/detector section)
20. DCS/SAR receiver
21. DCS/SAR transmitter
22. To X-band antenna
23. Signal processing section
24. Circularly polarized wave feeder
25. To signal synthesizer circuit
26. L-band quadrifilar helical antenna
27. Down[-link]



- Upper, lower left: MESSR scanning radiometer section
- Upper right: MESSR high speed data transmission section and the apparatus for performance evaluation
- Middle right: MESSR signal processing section and the apparatus for performance evaluation
- Lower right: Apparatus for a performance evaluation of the MESSR

## Launch/Operation

MOS-1 will be launched by the N-II launcher from the Tanegashima Space Center. When the satellite reaches an altitude of 913 km, its second stage points the attitude of the satellite for insertion into the planned orbit. The satellite will be separated from the launcher over South America, and it will be inserted into a solar synchronous, semi-recursive orbit. After damping the nutation, which may occur after separation, is confirmed, the solar cell paddle will be extended, the satellite's pitching axis will be arrested, the sun will be traced by the solar cell paddle, and then the satellite will begin to track the sun. Orbital insertion errors will be corrected by the gas jet system within a week. During launching and the initial stages, the Tsukuba Space Center will serve as the central tracking and control station. Tracking and control of the satellite will be carried out by the Masuda tracking and control station, which will serve as the main station, with the help of Katsuura, Okinawa, and a down-range station (in the Caroline Islands, on a ship, or in South America).

The attitude of a satellite in orbit is disturbed by solar radiation pressure, gravitational inclination, and residual magnetism. Maintenance of the attitude against external disturbances and unloading are all processed on board without interference from the ground stations. The external disturbances that affect the satellite's orbit are the gravitational forces of the moon and the sun, solar radiation pressure, and atmospheric resistance. The altitude is maintained within  $\pm 390\text{m}$ , and orbital corrections are carried out approximately every 300 days.

In stationary stages, housekeeping and stationkeeping are carried out by the Tsukuba Space Center through Masuda and Katsuura tracking stations and the Okinawa tracking and control station, which will serve as the main tracking station. Housekeeping data, which are collected during the time zones that cannot be observed directly from the Japanese stations, are recorded on the data recorder and then replayed in the visible time zone. The operation of mission equipment is controlled by the Earth Observation Center. Observed and telemetry data will be provided to overseas data receiving stations by using stored commands.

### An example of the launch sequence

| <u>Elapsed time (seconds)</u> | <u>Events</u>   |
|-------------------------------|---|
| 0                             | Lift-off  |
| 282 (4 minutes 42 seconds)    | Separation of the first and second stage                        |
| 288 (4 minutes 48 seconds)    | The first ignition of the second stage engine                   |
| 297 (4 minutes 57 seconds)    | Fairing separation  |
| 679 (11 minutes 19 seconds)   | The first burning of the second stage engine completed (SECO 1) |
| 3412 (56 minutes 52 seconds)  | The second ignition of the second stage engine                  |
| 3421 (57 minutes 1 second)    | The second burning of the second stage engine stopped (SECO 2)  |
| 3481 (58 minutes 1 second)    | Satellite separation  |
| 3577 (59 minutes 37 seconds)  | Start extending the solar cell paddle                           |
| 3697 (61 minutes 37 seconds)  | Arrest pitching   |
| 5137 (85 minutes 37 seconds)  | Start rotating the solar cell paddle                            |
| 5737 (95 minutes 37 seconds)  | Start corrections for the solar cell paddle                     |
| 6037 (100 minutes 37 seconds) | Complete corrections for the solar cell paddle                  |



Key: [to page 52 figures]

[Figure in upper left corner]

1. Fairing envelope
2. Attach fitting

[Large globe figure in center--  
starting in center of globe and moving  
counterclockwise with line]

1. Lift-off
2. 282 seconds; the first and second stage separate; 288-679 seconds; the second stage engine is ignited for the first time
3. 297 seconds; fairing separates
4. 740-940 seconds; control pitching during the coast phase; control yawing during the coast phase
5. 3412-3421 seconds; the second stage engine is ignited for the second time
6. 3481 seconds; the satellite separates
7. 3577 seconds; extension of the solar cell paddle starts
8. 3697 seconds; pitching is arrested
9. 5137 seconds; the solar cell paddle begins to rotate
10. 5737-6037 seconds; corrections for the solar cell paddle are applied

[Global system on right]

Solar synchronous orbit; the orbital plane rotates once a year with respect to an inertial system, and the angle between the sun and the orbital plane is kept almost constant.

|                 |         |
|-----------------|---------|
| [center circle] | The sun |
| [north globe]   | Winter  |
| [east globe]    | Fall    |
| [south globe]   | Summer  |
| [west globe]    | Spring  |

1 MOS-1 システム運用モード表

| 2<br>サブシステム      | 3<br>モード           | 4<br>打上げモード | 5<br>初期捕捉モード | 6 軌道上モード    |                        |                |               |              |       |      |         |      |     |
|------------------|--------------------|-------------|--------------|-------------|------------------------|----------------|---------------|--------------|-------|------|---------|------|-----|
|                  |                    |             |              | 7<br>不可視モード | 8 日照モード                |                |               |              |       |      | 9 日陰モード |      |     |
|                  |                    |             |              |             | MESSR<br>+VTIR<br>+MSR | MESSR<br>+VTIR | MESSR<br>+MSR | VTIR<br>+MSR | MESSR | VTIR | MSR     | VTIR | MSR |
| 10<br>ミッション機器    | 可視近赤外放射計(MESSR)    | 11          |              |             | ●                      | ●              | ●             |              | ●     |      |         |      |     |
|                  | 可視熱赤外放射計(VTIR)     | 12          |              |             | ●                      | ●              |               | ●            |       | ●    |         | ●    |     |
|                  | マイクロ波放射計(MSR)      | 13          |              |             | ●                      |                | ●             | ●            |       |      | ●       |      | ●   |
|                  | DCS/SAR 中継器        | 14          |              | ●           | ●                      | ●              | ●             | ●            | ●     | ●    | ●       | ●    | ●   |
|                  | 通信系/アンテナ系          | 16          |              |             |                        |                |               |              |       |      |         |      |     |
| 15<br>バス機器       | VHF 送信機            | 17          | ●            | ●           |                        |                |               |              |       |      |         |      |     |
|                  | VHF 受信機   UHF アンテナ | 18          | ●            | ●           | ●                      | ●              | ●             | ●            | ●     | ●    | ●       | ●    | ●   |
|                  | Sバンド送信機            | 19          | ●            | ●           | ●                      | ●              | ●             | ●            | ●     | ●    | ●       | ●    | ●   |
|                  | Sバンドダウンリンクアンテナ     | 20          | ●            | ●           | ●                      | ●              | ●             | ●            | ●     | ●    | ●       | ●    | ●   |
|                  | Sバンド受信機            | 20          | ●            | ●           | ●                      | ●              | ●             | ●            | ●     | ●    | ●       | ●    | ●   |
|                  | Sバンドアップリンクアンテナ     | 20          | ●            | ●           | ●                      | ●              | ●             | ●            | ●     | ●    | ●       | ●    | ●   |
|                  | Sバンドトランジションアンテナ    | 21          | ●*           | ●*          | ●                      | ●              | ●             | ●            | ●     | ●    | ●       | ●    | ●   |
|                  | USB 送信機   USB アンテナ | 22          |              |             | ●                      |                | ●             | ●            |       |      | ●       |      | ●   |
|                  | 太陽電池パドル系           | 23          | ●            | ●           | ●                      | ●              | ●             | ●            | ●     | ●    | ●       | ●    | ●   |
|                  | ガス ジェット系           | 24          | ●            | ●           |                        |                |               |              |       |      |         |      |     |
| 軌道補正のため 1 年に数回使用 |                    |             |              |             |                        |                |               |              |       |      |         |      |     |
| 26               |                    |             |              |             |                        |                |               |              |       |      |         |      |     |
| 25               |                    |             |              |             |                        |                |               |              |       |      |         |      |     |
| 27               |                    |             |              |             |                        |                |               |              |       |      |         |      |     |
| 28               |                    |             |              |             |                        |                |               |              |       |      |         |      |     |

●: 使用するサブシステムあるいは機器  
\*: 送・受信用(他は受信用として用いる)

Key:

- Table of system operating modes for MOS-1
- Subsystem
- Mode
- Launch mode
- Early arrest mode
- In-orbit mode
- Invisible mode
- In-the-sun mode
- In-the-shade mode
- Mission equipment
- Visible near-infrared radiometer (MESSR)
- Visible thermal infrared radiometer (VTIR)
- Microwave radiometer (MSR)
- DCS/SAR relay
- Bus equipment
- Communication and antenna systems
- VHF transmitter
- VHF receiver; UHF antenna
- S-band transmitter; S-band down-link antenna
- S-band receiver; S-band up-link antenna
- S-band transition antenna
- USB transmitter; USB antenna
- Solar cell paddle system
- Gas jet system
- Attitude orbit control system; telemetry/command system; power supply system; thermal control system
- Used several times a year to correct the orbit
- : Subsystem or equipment used
- \*: For both transmitting and receiving (others are for receiving only)

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## 世界の人工衛星における NEC の実績

## ●国内

|      |                             |                            |             |  |                 |               |                  |
|------|-----------------------------|----------------------------|-------------|--|-----------------|---------------|------------------|
| 試験衛星 | 我が国初の人工衛星<br>L-4S-5<br>おおすみ | MS-T1<br>たんせい1号            |             |  | MS-T2<br>たんせい2号 | JETS-1<br>きく  |                  |
| 科学衛星 | MS-F1<br>(打上げ失敗)            | 我が国初の科学衛星<br>MS-F2<br>しんせい | REXS<br>でんぱ |  |                 | SRATS<br>たいよう | CORSA<br>(打上げ失敗) |
| 実用衛星 |                             |                            |             |  |                 |               | ISS<br>うめ        |

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32 41

## ●海外 (NEC参加分のみ)

|      |  |                                     |                  |                     |    |                             |                   |
|------|--|-------------------------------------|------------------|---------------------|----|-----------------------------|-------------------|
| 科学衛星 |  | 火星探査<br>マリナ8号 マリナ9号<br>(打上げ失敗)      | 木星探査<br>バイオニア10号 | 木星、土星探査<br>バイオニア11号 |    | 火星探査<br>バイキングA/B            |                   |
| 実用衛星 |  |                                     |                  |                     |    |                             |                   |
| 気象衛星 |  |                                     |                  |                     |    |                             |                   |
| 通信衛星 |  | 初の本格的<br>商用通信衛星<br>インテルサット IV<br>F2 |                  | F7                  | F8 | インテルサット IV<br>F6 (打上げ失敗) F1 | マリサット<br>F1 F2 F3 |

35 36

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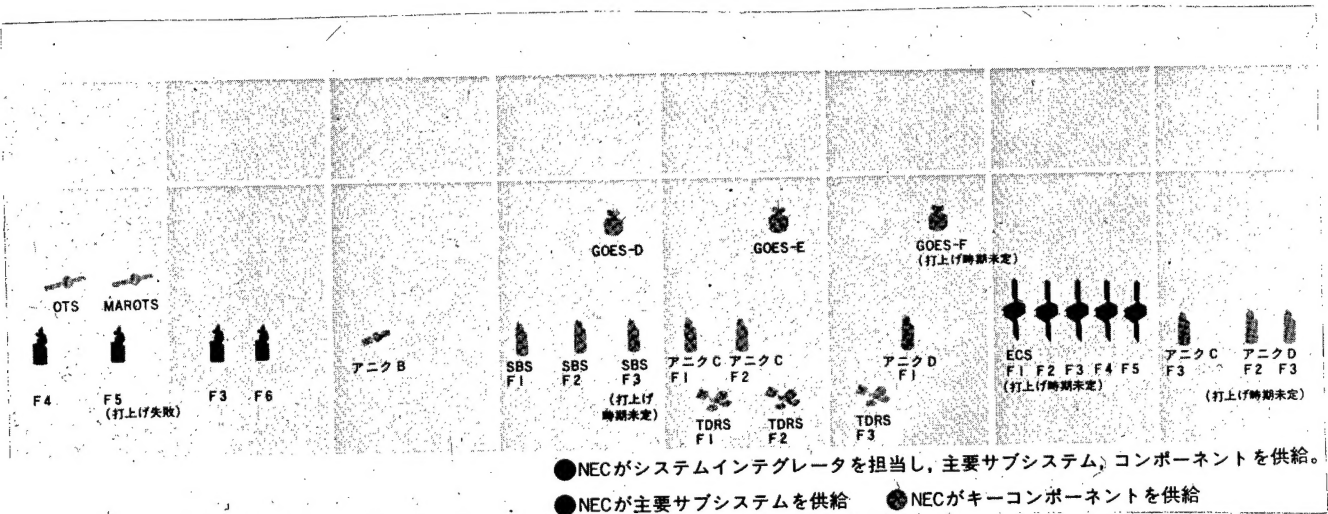
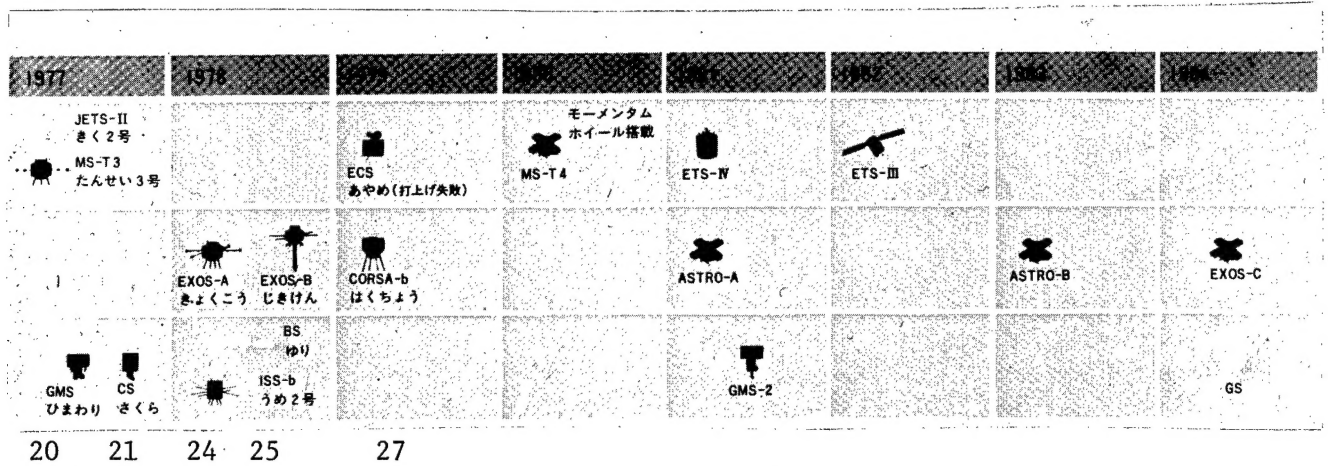
42

43

## Key:

- Worldwide achievements of NEC in artificial satellites
- Domestic
- Experimental satellites
- Scientific satellites
- Satellites for practical applications
- First artificial satellite of Japan
- Osumi
- (Launch failed)
- Tansei No 1
- First Japanese scientific satellite
- Shinsei
- Dempa
- Tansei No 2

- Kiku
- Taiyo
- (Launch failed)
- Ume
- Kiku No 2
- Tansei No 3
- Himawari
- Sakura
- Kyokko
- Jikiken
- Yuri
- Ume No 2
- Ayame (launch failed)
- Hakucho
- Momentum wheel installed onboard
- Overseas (only those in which NEC participated)



16

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30. Meteorological satellites
31. Communications satellites
32. Mars exploration
33. Mariner No 8 (launch failed)
34. Mariner No 9
35. First full-scale commercial communications satellite
36. Intelsat IV
37. Jupiter exploration
38. Pioneer No 10
39. Jupiter and Saturn exploration

40. Pioneer No 11
41. Viking A/B
42. Intelsat IV A
43. Marisat
44. Anik
45. (Launch date undecided)

- NEC took the role of a system integrator, and provided major subsystems and components
- NEC supplied major subsystems
- NEC provided key components



Key:

- |                          |   |
|--------------------------|---|
| 1. Osumi                 | 21. System integration testing                    |
| 2. Tansei                | 22. Common subsystems engineering                 |
| 3. Intelsat IV F2, F6-F1 | 23. Integration hardware                          |
| 4. Shinsei               | 24. Airframe system hardware                      |
| 5. Dempa                 | 25. Thermal control system hardware               |
| 6. Tansei No 2           | 26. Communications system hardware                |
| 7. Taiyo                 | 27. Power supply system hardware                  |
| 8. Kiku                  | 28. Attitude orbit control system hardware        |
| 9. Ume                   | 29. Onboard processor                             |
| 10. Tansei No 3          | 30. Mission system subsystem engineering          |
| 11. Himawari             | 31. Mission system hardware                       |
| 12. Sakura               | 32. Communication/data processing system hardware |
| 13. Kyokko               | 33. Support engineering                           |
| 14. Ume No 2             | 34. Ground support apparatus                      |
| 15. Jikiken              | 35. Ground facilities/installations               |
| 16. Hakucho              | 36. Launch support operations                     |
| 17. Ayame                | 37. Operation support tasks                       |
| 18. Systems engineering  | 38. Analysis/evaluation operations                |
| 19. Program management   | 39. By ourselves                                  |
| 20. System design        | 40. In cooperation with foreign firms             |

[Back cover]

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October 1979

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CSO: 8129/0238

- END -